Production Technology: Theory and practice

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Lecture – 04
Metal Machining 1- Introduction to Machining

Hello and welcome back to our discussion session. So far we have discussed the engineering materials and material properties. Now, we will start discussing metal machining. This is our second module; here we will discuss different kinds of machining operations, conventional machining operations, and how they are performed. And what is the physics behind the processes, how the forces are obtained? How the forces are related to other parameters?

We will discuss the factors on which factors the forces and the power consumption depend. Any part can be manufactured and fabricated in three different ways, it can be fabricated without changing the initial volume of the raw material. Those processes are called the constant volume operations or constant mass operations, the mass is not changed rather.

Those processes, as you know, are casting, metal forming etcetera where the final mass and the initial mass remain the same. No excess material is removed. The parts can also be fabricated by removing excess material from the workpiece surface. Those processes are called the machining processes. That exactly we will be discussing in our discussion right now. And the third process is when the material is added to the initial material that is to the blank.

Those processes are welding, rapid prototyping, or the recently developed 3-D printer. There layer by layer the material is added on the base and the final product is made. In welding other parts are attached to the base part; joining for example Here the mass is added. Now, these are the three processes.

For any fabrication, let us see how many engineering disciplines are involved to get the final product. First of all, we will start from the ore. So that ore is in the Mother Earth, somewhere we do not know. We involve geologists, geophysics specialists to find out where exactly the ore is available, let us say iron ore, or for that matter, aluminium ore, copper ore and other materials.

Now, when the geologists and geophysicists find out the place it has to be extracted, then the mining people are involved there to extract the ore, and transport it to the metallurgist people. Metallurgists in its turn, melt it, segregate the metal from the ore and they get the kind of raw material.

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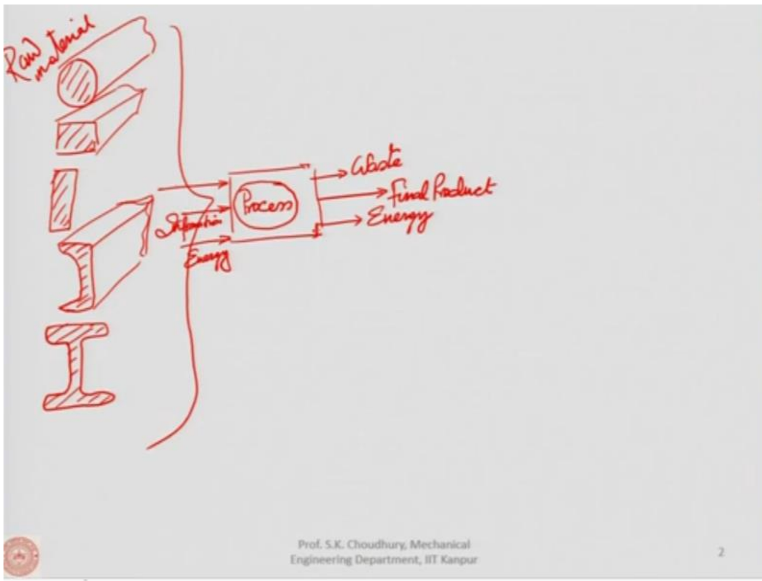

The raw material can be of round shape, like that. It can be a square shape. It can be a rectangular shape. Or it can be of this shape, let us say angles. These raw materials are produced after the ore is melted, the metal is segregated from the ore and the long rods like this are produced.

Now, these raw materials go through a process. In this process apart from the raw material we have to have the certain kind of information; we have to have certain sort of energy. And as the output we will have the final product or finished product, we will have some waste as well.

We will have some energy in the form of heat energy, where the mechanical energy that you are putting in the process is converted to the heat output. That is also a kind of an energy which we are getting at the output of the process. These are the processes which we call as the manufacturing processes. It can be as I said constant mass operation, it can be material removal operation or it can be mass addition process. Since we will be discussing the machining processes mostly here, let us see what is the position of machining .

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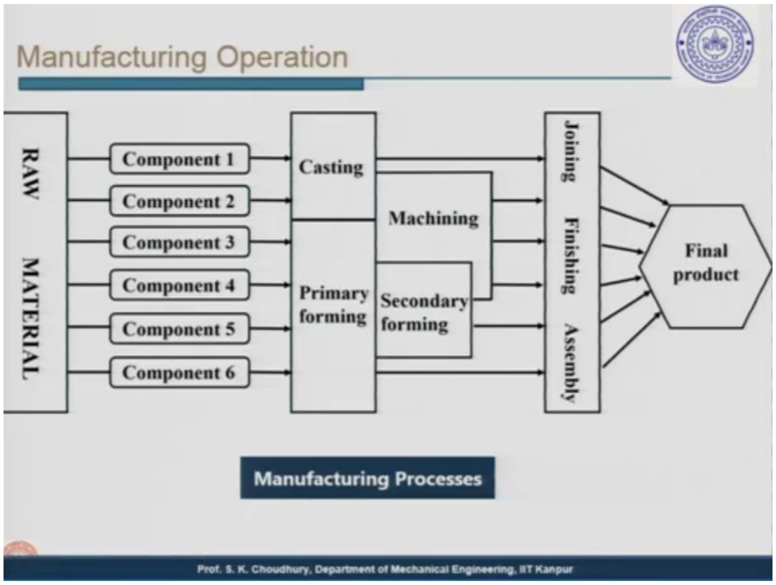

These are the raw materials and let us say from here the component 1, component 2 and there are 6 components altogether from this raw material. Now, component1, let us say, will go through the casting and then it will go through joining, finishing or assembly to get the final product. Similarly, component number 2 will go through casting then it will go through machining then it will be going for the joining, finishing or assembly.

Similarly, you can see that all components need not to go through a particular process or all the processes. For example, let us take the component 1, you know that there are precise casting processes like lost wax method, investment casting I mean, or a high pressure casting. After those precise casting processes, the part quality will be final and the dimensions will be adhered to. Therefore, after the casting particularly for those castings where we have a very high precision in the process, there no other process would be required.

So, it will directly go for the joining or go for the assembly or a component may need after casting some sort of machining, because after casting either the sides are not exactly perpendicular or the surface finish is not very good or some dimensions are not proper. The machining is involved in correcting or finishing the casting part. Some component may need even primary forming and then secondary forming.

And then it can only go for the assembly or joining or finishing and then it will come as a final product. Now, that means you can see that first of all not all components need to go through all these processes and here is the machining process. The role of machining process in these manufacturing processes like casting, primary forming as we said, this is the constant mass operation, whereas machining is the material removal operation.

Secondary forming is like primary forming, it will be the constant mass operation. Joining, assembly - these are mass addition processes. The example of is welding. The role of machining in the manufacturing processes is really great in the sense that 80 to 90% of the product in the industry go through the machining.

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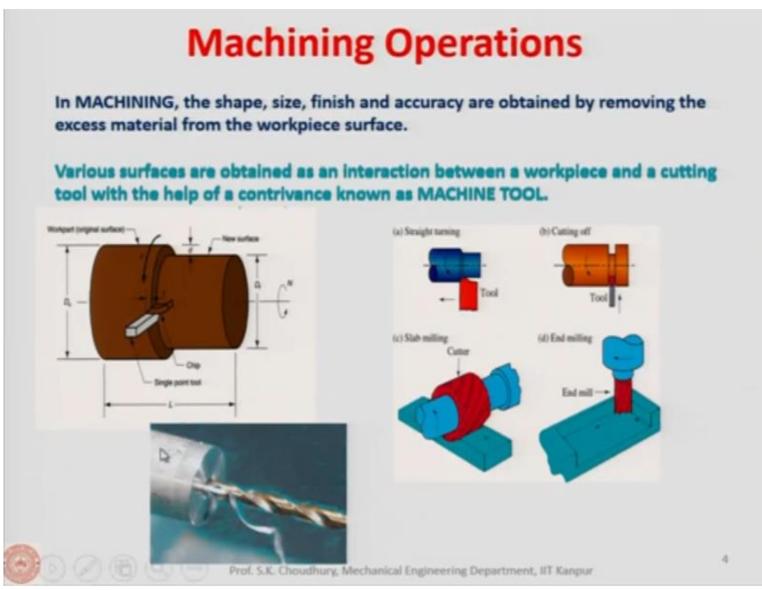

Let us discuss machining. By definition, machining is one of the manufacturing processes by which the shape, size, finish and accuracy are obtained by removing excess material from the workpiece surface. Initially I said that the machining process is the material removal process. And this is the process in which the shape, size, finish and accuracy are obtained by removing the excess material. That excess material is removed in terms of small chips, with the help of a tool and with the help of a contrivance which is called a machine tool.

If it is a turning process, the machine tool is the lathe machine, for milling process, it is a milling machine and so on.We will see those machines in the laboratory. Now, various surfaces are obtained as an interaction between the workpiece and the cutting tool with the help of a contrivance known as a machine tool. Depending upon the relative movement between the tool and the workpiece, we can get different surfaces.

Let us consider some examples. Let us say that the workpiece is rotating either clockwise or anti-clockwise and the tool is moving parallel to the workpiece surface. As you know that in that case, you can get an external cylindrical surface or an internal cylindrical surface . In case if the tool is a boring tool, which will be attached to the tailstock and it will not be rotated, it will be moving parallel to the axis of the workpiece, an internal cylindrical surface is generated.

If the tool does not move parallel to the workpiece axis, but at an angle then we can get an external taper surface or an internal taper surface. If the tool moves perpendicular to the workpiece axis, then it is a facing operation. What do we get in that case is a flat surface; we can also have a knurled surface, we can have a threaded surface and so on. So, these are the various surfaces that we can fabricate by particularly turning process depending on the relative movement between the workpiece and the tool.

Similarly, we can get a hole, either a blind or a through one, by means of the drilling, by means of reaming; by tapping we can get an internal thread for example, we can get a flat surface, an inclined surface or a grooved surface in case of shaping or planning operation. We can get a flat surface, contour surface in milling and so on. So, different kind of intricate surfaces can be obtained by removing the excess material from the workpiece surface in terms of small chips with the help of the tool and the machine tool.

In this slide you see the turning process and here is the tool removing the excess material in terms of small chips. We are getting the finished surface, a new surface by removing the excess material. Let us say that this is a cylindrical job and we are turning this cylindrical surface to reduce the diameter from D_0 which is the initial diameter.

And D_F is the finished diameter. In doing so we have to rotate the job. In case of turning and moving the single point turning tool along the axis or parallel to the axis of the workpiece we will get this kind of a surface. Now, this much is removed from both sides. This is the difference between the initial surface and the finished surface and that divided by 2 will be the depth of cut .

This is the theory; it is shown that how this uncut thickness can be obtained, that we will discuss in more details later on. Now, here if you see that this is the straight turning as in this case, this is the grooving. In case of grooving, the tool is given a feed which is perpendicular to the workpiece surface; in this case it is parallel to the workpiece surface, this is the feed direction. The feed is the linear distance the tool is covering in 1 revolution of the workpiece .

So, during each one revolution of the workpiece, how much the tool is moving in millimeter through the workpiece material is defined as the feed. Here the feed direction as you can see is perpendicular to the workpiece axis; this is an example of drilling. In case of drilling this is different than the turning. In case of drilling the workpiece does not rotate; workpiece is fixed on the table and the tool, which is the drill, rotates as well as penetrates.

This penetration is the thrust force which is important to the tool that is the drill and it also rotates. Both the feed motion and the cutting motion will be given to the tool. Now what I mean by cutting motion is if you see here this is the diameter depending on the number of revolutions, N that is the RPM, revolution per minute, we can find out what is the cutting speed.

The cutting speed, V is decided by the initial diameter of the workpiece and this is given by πDN , D is the initial diameter. So, depending on the RPM and the revolution of the workpiece and the diameter of the workpiece you can find out the cutting speed. In case of drilling the cutting speed will be given to the drill, drill rotates.

Here also depending on the RPM of the drilling machine or the drill, at which frequency it is rotating, and the drill diameter, you can find out the cutting speed that means at which speed the drill is rotating. Similarly, in case of milling if you see here this is the milling cutter, the milling cutter is mounted on the arbor, this is the arbor of the milling cutter on the machine, here it is horizontal, and here it is vertical.

This kind of machines where such operation is performed is called the horizontal milling machine and these kinds of operations performed on the vertical milling machines. In this case it is called the end milling cutter and this is called a slab milling cutter. Here if you can see that these are the spiral milling cutters, the teeth are not straight, but they are spirally located at the periphery of the work of the tool.

In this case, it is a flat surface which is produced, here you can see there is a pocket produced, it may be a blind it may be through and so on and here the hole is produced. By drilling you can make an internal hole which may be through hole or it may be a blind hole that means it may not be going along the full depth of the workpiece.

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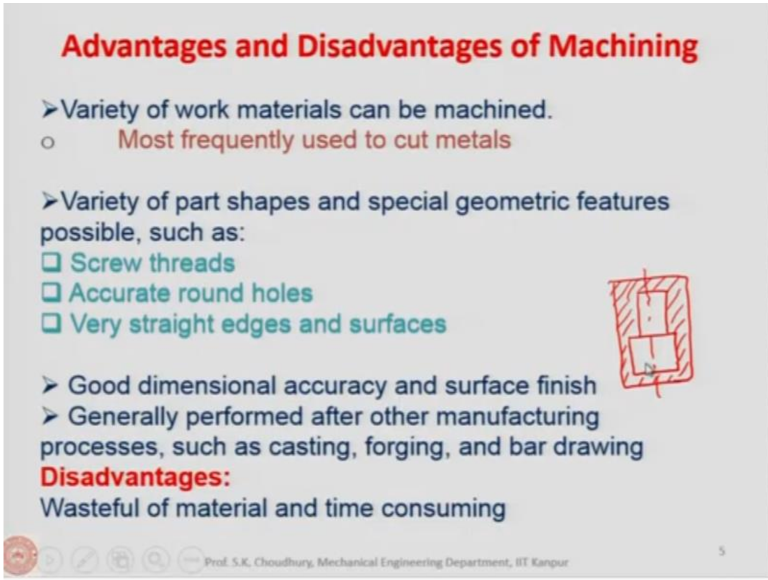

Now, what are the advantages and disadvantages of machining? In advantages, a variety of work materials can be machined. Like we said, both hard or soft materials can be machined, plastic materials can be machine and so on. This may not be possible in some other processes. Most frequently used to cut metals, to remove excess material from metals. Second point is that variety of part shapes and special geometric features is possible to produce such as screw threads, accurate round holes, very straight edges and surfaces.

These are the advantages of machining. In case of metal forming or casting, you can cast threads, you can make threads in the metal forming process by cold rolling but the accuracy that you will be getting in machining will be higher than in case of cold rolling or thread obtained by casting, it has to go through the machining to get the proper accuracy. That is is the importance of machining.

Next is the good dimensional accuracy and surface finish in machining. Generally machining is performed after other manufacturing processes such as casting, forging and bar drawing. As I was telling that initially the part will be casted or bar drawn or forged and then the final shape, final finish, final accuracy will be given by machining. Only disadvantage is a wasteful of material and time consuming because it is the removal of excess material.

If you want to get a part like this, for that you have to get blank which will be of this type, let us say, this is the material - this is called the allownce, this material has to be removed. So, this is the waste of material, this material, in terms of small chips, will be removed. So, that cannot be used, chips cannot be used to re-melt unlike casting because they are very hard material.

Their properties are changed since they have gone through the strain hardening. So, this is the waste of material. In case of casting or metal forming or in case of powder metallurgy, this kind of situation does not arise. Wastage of material is considered to be one of the biggest disadvantages and probably the only disadvantage of the machining.

That it is the wasteful of material and of course, time consuming, because if you want to make this product in metal forming for example, it could be made in a much faster way.

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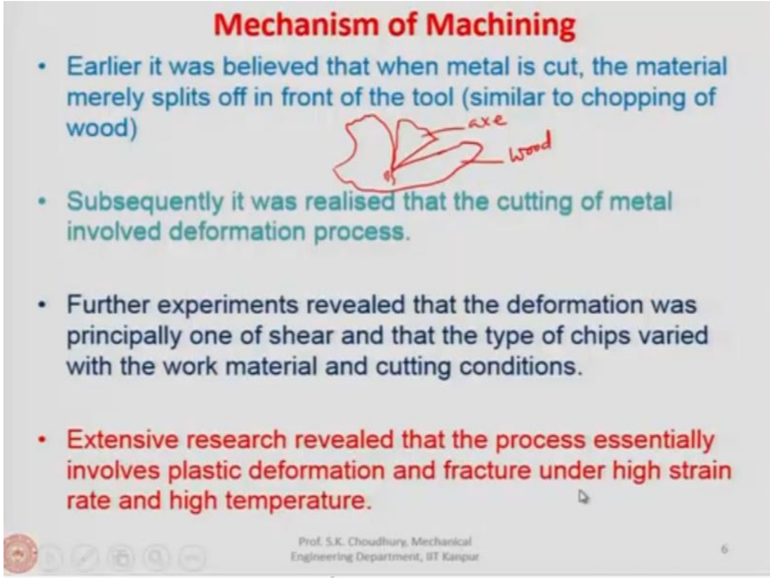

Let us discuss the mechanism of machining, Earlier it was believed that when metal is cut, the material merely splits off in front of the tool, similar to chopping of wood. Let us say this is a wooden piece, and this is the axe. While chopping wood, once you hit with the axe there is a crack formed in front of the axe and that crack is propagated and then the material is segregated from the base material.

So, it was assumed initially that metal also is cut with the help of crack propagation or it helps. Subsequently it was realized that the cutting of metal involves deformation process, it is not the splitting of the wood in front of the axe and then propagating the crack, but it is some sort of deformation process. Further experiments revealed that the deformation was principally one of the shear types, that is a shear deformation. And that the type of chips varied with the work material and cutting conditions.

The types of chips that you will be getting will be either a continuous or discontinuous chip or serrated chips, or a built-up edge is formed. All that depends on the cutting process parameters that you have selected; cutting parameters we will discuss in more details later. These are mainly the cutting speed, feed, and depth of cut.

Extensive research revealed that the process essentially involves plastic deformation. The deformation is a plastic deformation and fracture under the high strain rate and high temperature. High strain rate is imparted by the cutting force. There is a prime mover, which through the lead screw moves the tool; we will see that in the lab as well. Through that we are imparting certain cutting force. Cutting force multiplied by the cutting velocity will be the cutting power.

That power is given to the cutting process so that the material is removed. That creates very high strain rate of deformation and high temperature. High temperature because the material is plastically deformed and most of the heat is produced because the material is plastically being deformed, and then when the material is removed, the removed material in terms of small chips, slides over the rake face of the tool.

Friction between the chip and rake face of the tool creates further temperature. So, the temperature because of the plastic deformation added to the temperature due to friction and that together gives very high rise in the temperature.

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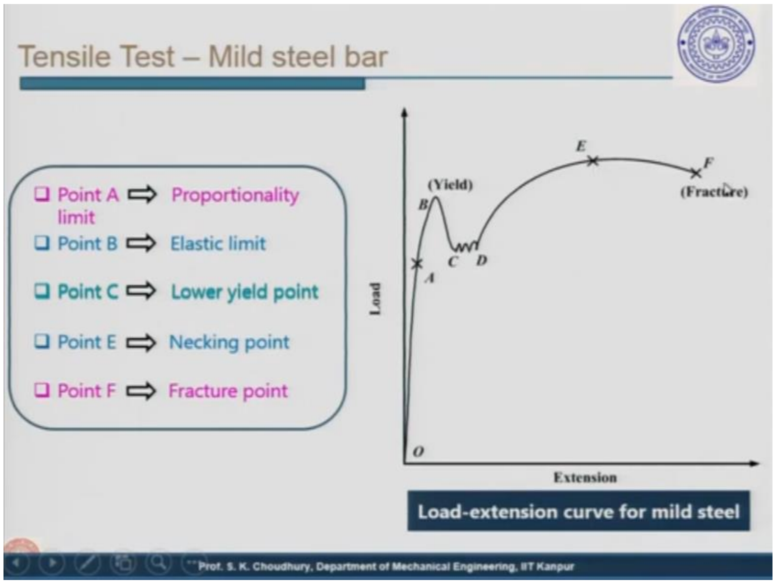

Therefore, when we do the tensile test particularly of a mild steel bar, this reveals what is deformation? What is particularly plastic deformation? This is for the ductile materials not for the brittle materials.

Therefore, the curve will go all the way up to the fracture, means the segregation of the excess material from the base material, from the workpiece. This curve helps us to understand what is plastic deformation and I have already explained this curve to an extent during the discussion on materials and their properties. I will go through a little faster but here are some of the details which we have not discussed and I would like to add here.

Now, we know that point 1 is the proportionality limit, this is the elastic limit. Then we have the point C which is the lower yield point, this is the upper yield point. Then we have the E which is the necking point and then here the metal fractures.

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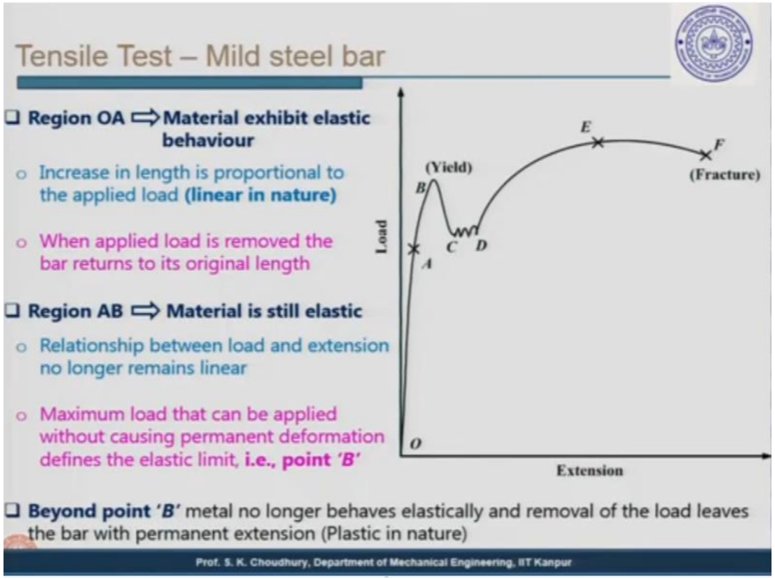

Region OA exhibits elastic behaviour which means increase in length proportional to the applied load. This is linear in nature. When applied load is removed, the bar returns to its original position, original length; then comes the AB; AB it is no more linear but material is still elastic. The relationship between load and extension no longer remains linear and this is the maximum load that can be applied without causing permanent deformation.

This is still not the permanent deformation because even at this point, just below this point, if you remove the load, the specimen or the material will come back to the original length. Ttherefore the maximum load that can be applied without causing the permanent deformation defines the elastic limit. Up to that this is the elastic limit; beyond the point B, metal no longer behaves elastically and removal of the load leaves the bar with permanent extension.

So, plastic deformation already starts after the point B, meaning that after point B if we remove the load, the specimen or the material will not come back to the initial length and the deformation remains permanently.

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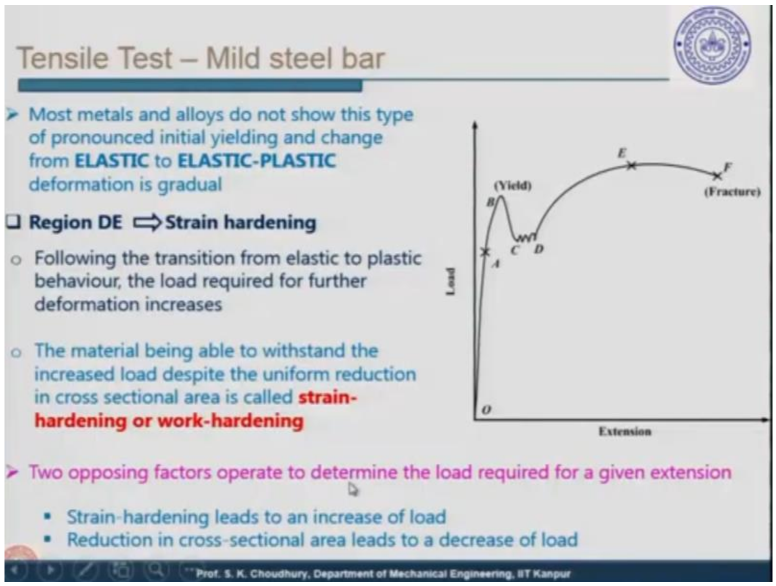

Just above the point B, this is called the upper yield point. And as I said that this is the lower endpoint, elastic behaviour of the material ceases and yielding starts. Stress at point B is normally called upper yield stress and this is lower yield stress. Now region CD has not been explained because this does not happen for all materials.

Yielding in mild steel is accompanied by a sudden drop in load and increase in length at approximately the constant load; it just fluctuates a little bit, but overall almost constant load. Stress at point C is called the lower yield stress; Upper yield stress and lower yield stress are characteristic of mild steel caused by the presence of small number of foreign atoms in the material.

These foreign atoms could be carbon and nitrogen etcetera. Most metals and alloys do not show this type of pronounced yielding. The case that I am showing you is the case of mild steel.

So, this is only characteristic for the mild steel, not all metals will have this kind of a characteristic. Now, most metals do not show initial yielding and change from elastic to elastic plastic deformation is gradual in most of the cases.

Region DE is the strain hardening region. Following the transition from elastic to plastic behaviour, the load required for further deformation increases, but this increase in the load is not linear, this is nonlinear. The material being able to withstand the increased load despite the uniform reduction in the cross-sectional area is called the strain hardening.

In some books, you will find that this is also called the work hardening which are the same, work hardening or the strain hardening. Two opposing factors operate to determine the load required for a given extension, this is strain hardening that leads to an increase of load and the reduction in the cross sectional area that leads in the decreased of load, just these two factors.

It is very important to understand that this is a contradictory factor; the strain hardening is sustained hardening, increases the load. Because material is hardened, more forces required to remove the material. Now, after the point E the necking starts, E is the point of instability; it is also called the point of instability because afterwards the material is unstable. After that, that means at this point of instability, the necking starts when the deformation happens locally.

Therefore, after necking starts, the load required will be less. Therefore, we are saying that two opposing factors operate to determine the load required for a given extension, strain hardening leading to increase in the load and reduction in the cross sectional area, that is the necking, leading to the decrease in the load.

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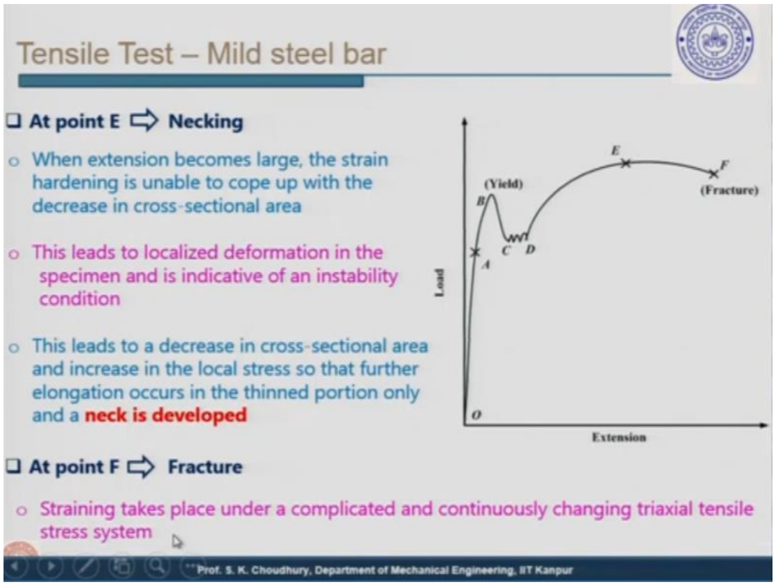

Point E as I said is the necking. When extension becomes large, the strain hardening is unable to cope up with the decrease in the cross sectional area, and the necking starts as localized deformation. This is indicative of an instability condition. This leads to a decrease in cross sectional area and the neck is developed, at point F, this is the fracture. In fact, point F is not defined; at any point after E the material can be segregated, material can fracture.

That varies from material to material, straining takes place under a complicated and continuously changing triaxial tensile stress system from E. From D to E it is still nonlinear, it is plastic deformation, it is a strain hardening and it is all predictable. As soon as this point starts, since the necking started and the deformation has become only localized therefore, it is erratic and you cannot predict anything and here from E to F straining takes place under a complicated and continuously changing triaxial tensile stress system.

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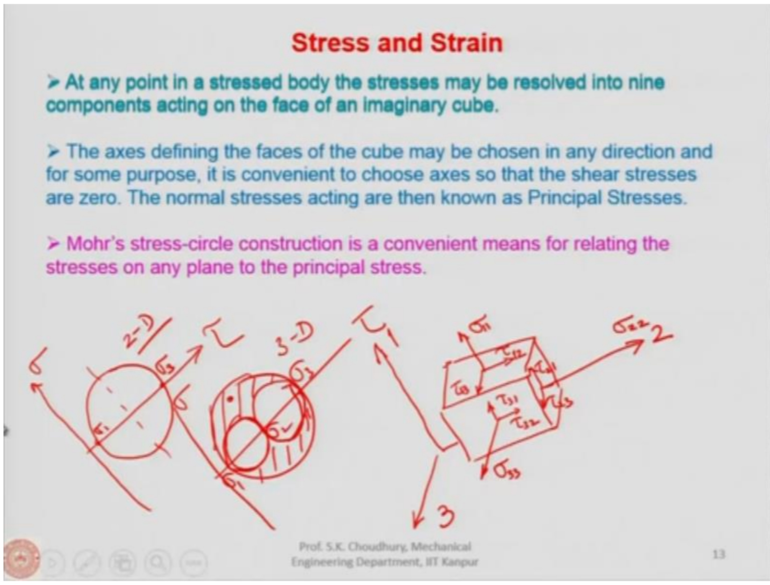

Stress and strain: we have to define as we have defined also in case of materials. The mode of deformation of a material under applied load will depend not only on the magnitude of forces and the mechanical properties of the material, but also on the way in which the forces are applied and combined. It is not only that what is the magnitude but how the forces are acting, at which point the forces are acting.

Nominal stress is defined as the load divided by the original cross-sectional area of the bar. This we have discussed earlier. We said that this is the engineering stress. The engineering stress is also called the nominal stress because here we can see that this is the original cross-sectional area of the bar. And now, you know that the difference between the engineering and the true stress is that in case of engineering it is original area.

In case of true stress it is the area on which the stress is applied. Now, engineering strain is defined as the extension per unit original length; again it is an engineering strain. And therefore, we have the length considered as the original length. The load extension diagram of a bar with unit cross sectional area and unit gauge length is therefore, the nominal stress strain curve for the material.

We mean that here we have the load and extension it can as well be expressed as stress here and the strain here, this is because, when the load extension diagram is taken for the unit cross sectional area and unit gauge length, but in that case this is the nominal stress and nominal strain or the engineering stress and engineering strain, not true strain. Stress when considered as acting perpendicular to a surface is called the normal or the direct stress, when parallel to a surface, they are called the shear stresses.

For a cube with 6 faces the stresses are like this, this is the normal stress or normal force, and if the direction is parallel to the surface, this is the shear stress, τ . This is the normal perpendicular to the face, and this is parallel to the face. So, this is the shear stress.

Now, at any point in a stressed body, the stresses may be resolved into 9 components acting on the face of an imaginary cube. Which are the 9 components? I am exaggerating that, so let us say we will put it in a system of axes. Let us say this is axis 1, this is 2, and this is 3. Here it will be σ_1 and σ_{11}, , σ_{22} normal and σ_{33}.

Then we will have the shear one like this, this will be τ_{12} then it will be like this, then this is the τ_{13} 1 towards 3. Similarly, here it will be τ_{21} these are the shear stresses this will be τ_{23}, this is τ_{32} and this is τ_{31}.. As you can see that there are 9 components of the stresses, 3 components will be normal stresses and 6 components will be shear stresses.

The axis defining the faces 1, 2, 3 we have taken in this case of the cube may be chosen in any direction, because that depends on us how you are choosing. That depends on how we want to define the faces of the cube. For some purpose it is convenient to choose axes, so that the shear stresses are 0. The normal stresses acting are then called the principal stresses.

Mohr's circle or stress circle construction is a convenient means of relating the stresses on any plane to the principal stress. In Mohr's circle this is the normal stress along the X-axis, this is the shear stress along the Y-axis . If it is 2-dimensional then this will be let us say σ_1, σ_3 and if it is the 3-dimensional of course, then it will be like this.

Here it will be 1, 2 and 3 these are the normal stresses, these are the shear stresses. This is the one that we are talking about, this is the 3-D and this is the 2-dimensional. Here we have stresses on the periphery and here it is inside, the stresses on a plane will be given as a point inside and in case of 2-dimensional case, it is on the periphery of the Mohr's circle.

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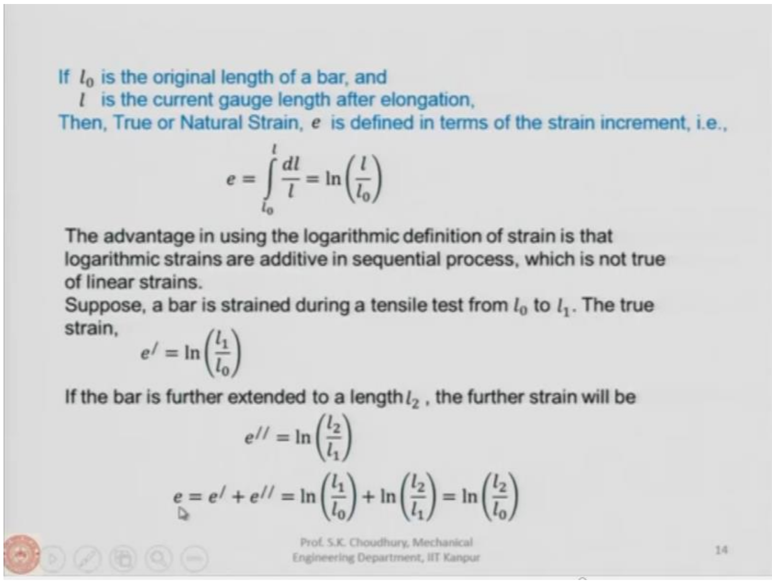

Now, if l_0 is the original length of a bar and l is the current gauge length after the elongation, then true or natural strain is defined in terms of the strain increments. The advantage in logarithmic scale is that it is additive in sequential process and how it is additive I have already shown to you earlier. So, you can see here that the length of the bar is changed from l_0 to l_1 and then to l_2 and so on.

Finally, what you will get is that total train will be equal to the ratio of final length and the initial length in logarithmic scale. Therefore, it is additive in the sequential process.

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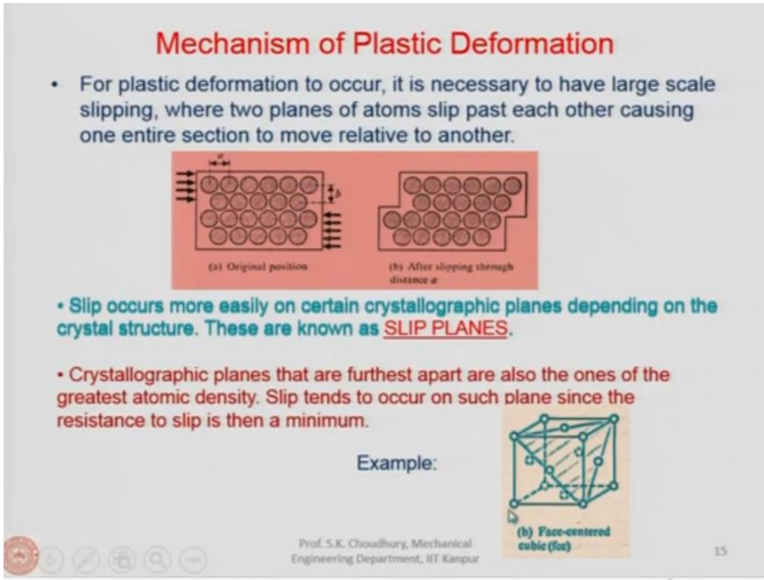

Now, let us see here, this is the mechanism of plastic deformation. We will try to explain that mechanism of plastic deformation in the atomic scale. Why it is important? Because any metal, any material for that matter, will have a lattice structure. The lattice structure contains the atoms and those atoms are sitting very peacefully in the sense that they are occupying their own space and the material is stable.

Now, if we disturb the position of the metal, position of the atom in the lattice structure, then the metal will be ‘annoyed’, meaning that they will try to resist the deformation that we are trying to make, that means that we are trying to disturb the position of the atoms. The position of the atoms can be disturbed only with very high force because they are very stable and that high force is considered to be the stress that we are applying or the high strain rate that we are applying to deform the material.

When we are deforming the metal we are also changing the position of the atoms, meaning we are shifting the layers of atoms, we are shifting few layers of the atom. That is deformation in the atomic scale. For plastic deformation to occur, it is necessary to have large scale slipping, where two planes of atoms slip past each other causing one entire section to move relative to another.

Look here. This is the lattice structure where atoms are stably located in their own space, this is the distance between the atoms. This is called inter atomic distance. This is the distance between the two layers, this is '*b'* and we are applying some shear force. This shear force creating shear stress and if the shear force becomes larger than certain value then only it will be able to displace two layers of the atoms over each other as shown here.

Now, let us say because of the application of the shear force, this layer is moving with respect to another layer, it has moved to this side over another. After slipping through the distance '*a'*, then the distance that has slipped, let us say it is '*a'*. Slip occurs more easily on certain crystallographic planes. It will not happen in any plane. I am going to explain on which planes it is possible for the slip to occur.

That means when you will deform the material, it will be deformed in a certain fashion, along the plane that is called the slip plane. Crystallographic planes that are farthest apart are also the ones of the greatest atomic density. Slip tends to occur on such plane since the resistance to slip is then minimum. Let me explain it to you that where you will find the slip plane.

Normally the slip planes are are those planes between the 2 layers of atoms which are most densely packed. Once they are most densely packed that means the resistance to the slip in between them will be less because they are very dense and they cannot resist further deformation. Therefore, the slip planes occurred or this deformation occurs between the layers which are most densely packed.

Now that are densely packed layers are also farthest apart from each other, that is another reason why we are saying that the deformation or the resistance to the deformation is less. So, the deformation occurs in between those planes because they are farthest apart since they are most densely packed. Now, in any material, you can actually find such a plane where you find most densely packed atoms. let us take an example.

This is a face centered cube. Face centered cube, as you know, is popularly known as FCC. Here on each face, at the center, atoms are located and that is why it is called the face centered cube. There is an atom on this face, an atom on this face, which is not visible; by dotted line it is shown that there is an atom. On the front face, there is an atom, at the back there is one, on this face there is one and at the bottom there is one.

Now if you draw a line between these 2 points and these points, then you will see that this plane which is shown here hatched, along this plane or on this plane we will have 9 atoms. You cannot draw any other plane where you will have more than 9 atoms. So, that is the plane we call as most densely packed atoms meaning that number of atoms on that plane will be more than on the other planes.

Then the distance between those 2 planes will be more because they are farthest and because they are most densely packed and therefore, the resistance to deformation will be less. Therefore, along this the plastic deformation occurs and these are the planes which are called the slip planes. Along that line on which the deformation occurs is called the slip line.

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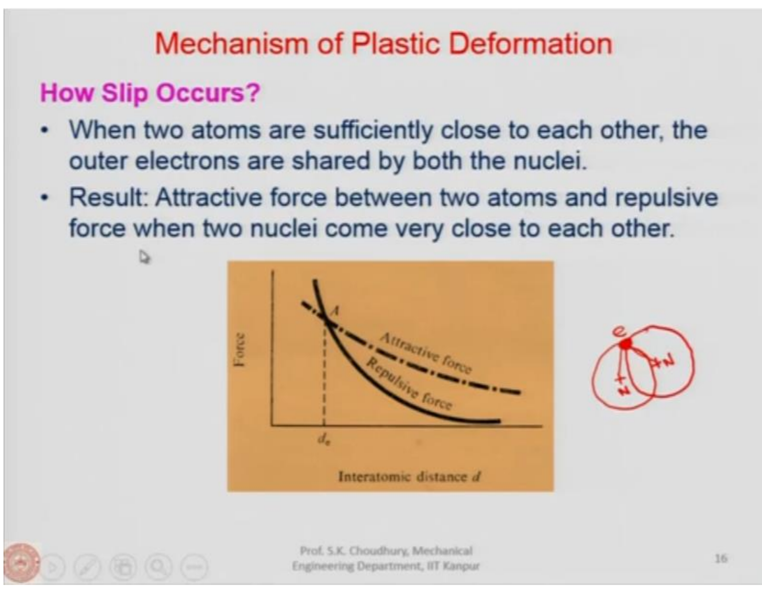

Now, let us see how slip occurs? When two atoms are sufficiently close to each other, the outer electrons are shared by both the nuclei. Suppose, you have an atom here, this is the nuclei, this is the electron let us say and there is one atom and another atom is very close, this is the nuclei of that atom. In that case, this outer electrons will be shared by both the nuclei. Let us say, this is ~~the~~ nuclei of one atom, this is nuclei of another atom and this electrons will be shared by both of them.

Now, what happens is that there is an attractive force between the electrons, and between the nuclei there is a repulsive force. Therefore, the atoms do not collapse because the electron is attracted by the neuclei. They are not collapsed because, as you know that when two atoms come closer to each other then there is a repulsive force between the nuclei. And here I have shown it to you through a curve.

Let us say this is the force and along the X-axis, if we put the inter atomic distance which is that distance between the two atoms, then both the attractive and the repulsive forces will be more when they come closer to each other. This is obvious since as they are coming closer to each other, the attractive force will be more and more because they are very close to each other.

Similarly, as they are coming closer to each other, the repulsive force will also increase. The nature of the repulsive force will be like this, as it is shown here. At less inter atomic distance, the repulsive force will be more; at less interactive distance the attractive force will be more, and as the distance is increasing both attractive force and the repulsive force decrease. Now, at a certain point you will see that these two curves are intersecting each other.

Therefore, at this point the atoms will be in equilibrium position. When the atoms are in the equilibrium position in a lattice structure that means either they have been deformed and they are in the equilibrium position or they are in the initial equilibrium position. There of course, the repulsive force and attractive forces will be the same.

Now, when two atoms are sufficiently close to each other the outer electrons are shared as I said. The result is that attractive force between the two atoms and the repulsive force when two nuclei will increase as they come very close to each other.

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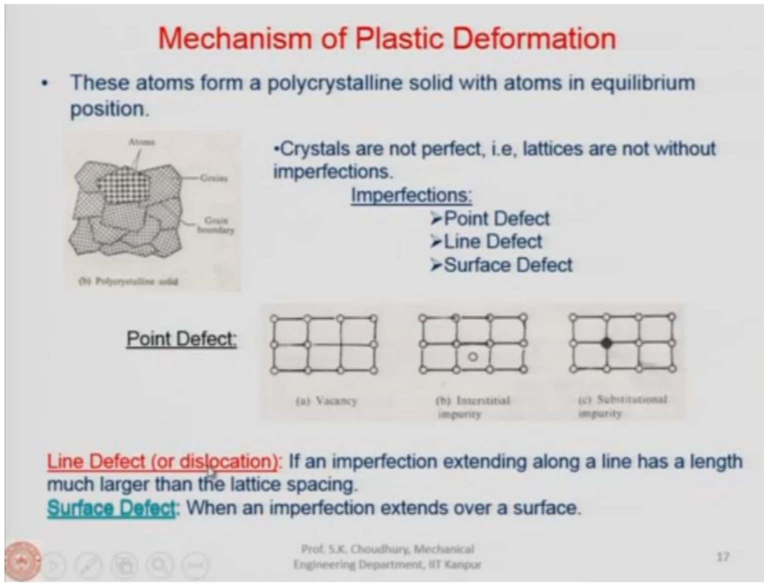

Now, these atoms form a polycrystalline solid with atoms in equilibrium position. Each of these is a grain and each grain has the lattice structure where atoms are in the equilibrium position. This is a poly crystalline solid. This is a crystal. These crystals are not perfect that is the lattices are not without the imperfection. Now what are the imperfections? Imperfections are also known as the defects.

Imperfections maybe point defect, line defect or surface defect - this you must have studied in somewhere in the material course that any crystal may have such kind of defect. What are those defects? What does it mean? Point defect maybe either vacancy or interstitial impurity or substitutional impurity. Now, what is vacancy is that here in a lattice structure all of a sudden in one atom is missing.

That missing atom has created a vacancy. In this lattice structure the atoms are in equilibrium position but in one place the atom is taking an abnormal position. All other atoms are in the normal position in their lattice structure, but this atom as you can see is taking an abnormal position. This is the imperfection or the defect that is called the interstitial impurity.

Here if you see in this lattice structure, it is in equilibrium position otherwise except in one place, there is a foreign atom, meaning this atom is not of this material, s it is coming from omewhere and it is occupying the space, occupying the place of the native atom. So, this kind of defect or imperfection is called the substitutional impurity. Now, there could be line defects that are also called the dislocation.

Dislocation or line defect is when the imperfection extending along a line. if one imperfection that can be a point defect and when this extends along a line having a length much larger than the lattice spacing, it is line defect. This is the lattice spacing and here, the imperfection extends along a line. Entire lattice has lattice spacing. If the imperfection goes beyond that length, then it is called the line defect.

And surface defect is when an imperfection extends over a surface. Now, this is also called the twinning meaning that when the deformed surface looks like a mirror image of the un-deformed surface. This is called the surface defect meaning that when the imperfection is all over the surface. The line defect is along a line and then the surface defect is along a surface. The rest of the things we will discuss in our next discussion session. Thank you.