Basics of Mechanical Engineering-2

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Week 06

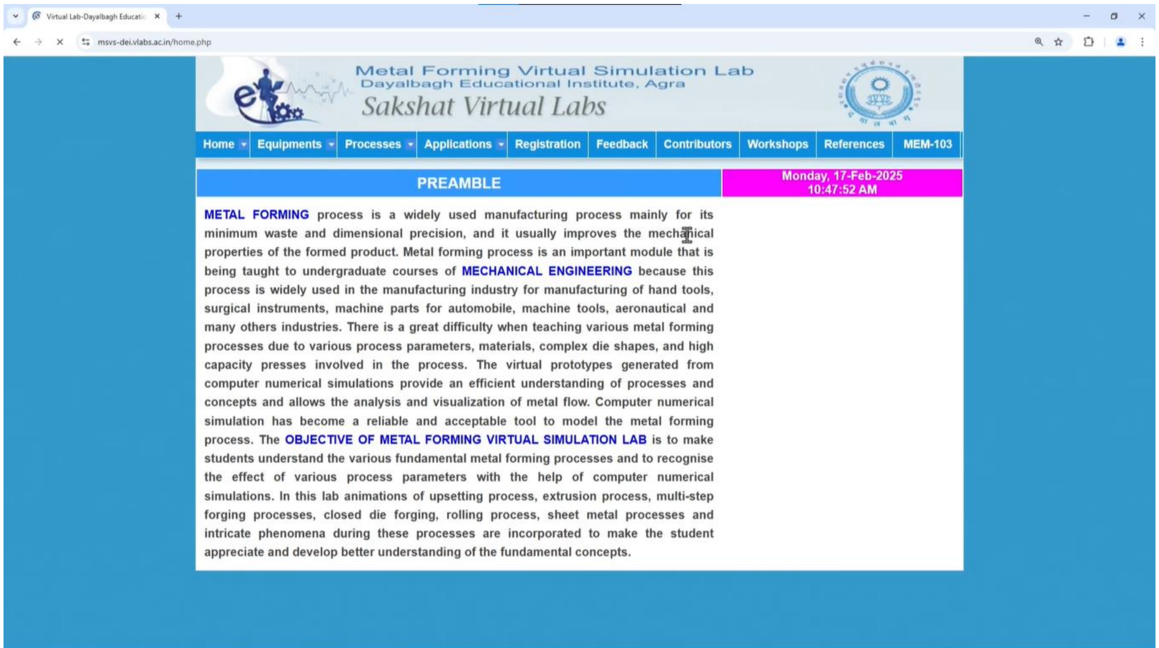
Lecture 23

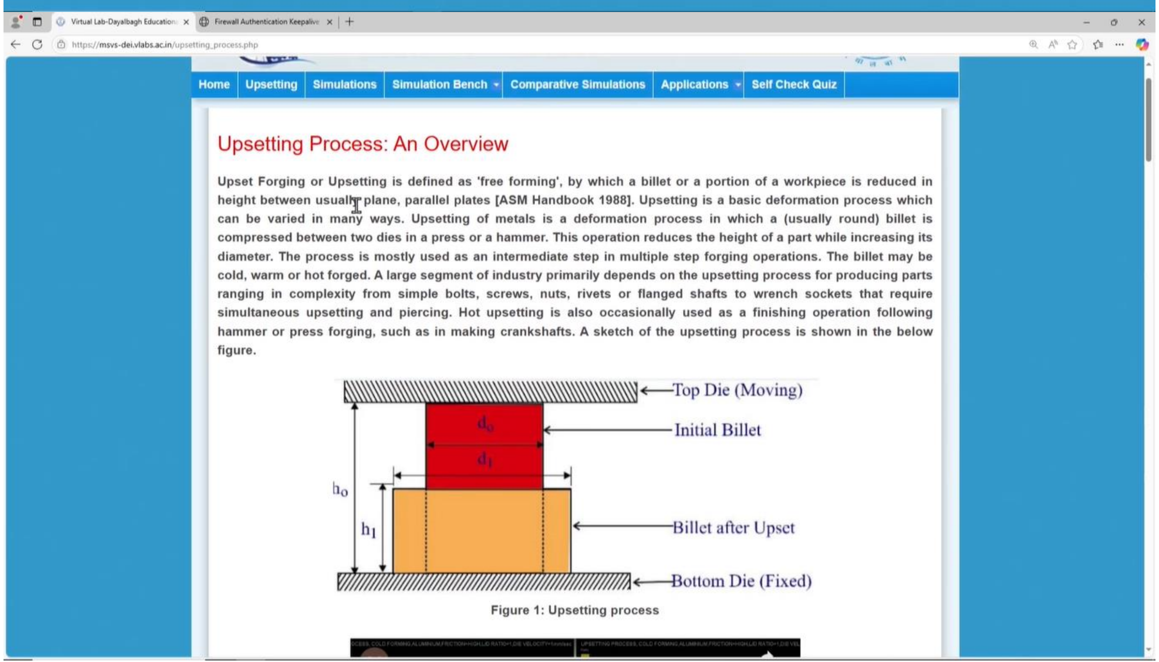
Virtual Lab. Demonstration (Forming)

Welcome to the virtual laboratory session on metal forming processes. We have discussed metal forming theory, the problem statements, and everything in the previous lectures. Now, the laboratory session: how does metal forming happen? The very general simulation. In the metal forming simulation that is available in virtual format, it is slightly different from what we did before. Here, generally, the CFD simulation—computational fluid dynamics simulation—is there, in which metal forming is being shown for different parameters.

You select, for example, hot forging. You select a specific temperature. You select a specific rate of the ram movement or so. You will see the forces and temperature changes. And that will be shown differently in different colors, which I will demonstrate here.

A complete laboratory is available for metal forming, developed by the virtual laboratory. First, I will come here to Google. I will search for 'virtual lab metal forming.' The first link you get here is the metal forming virtual simulation lab. I click here, and it opens.





So this is the interface of the virtual laboratory as you see. So, I am just zooming this out for you to appreciate and so that the visibility is better. So, we have home, wear motivation, metal forming applications. Applications in this you can see different kinds of applications of metal forming are given and all these theories given in home. In the equipment, different processes, upsetting processes and extruding processes are given.

In upsetting processes, different upsetting processes. For example, gravity drop, hammer description, gravity drop, hammer kinematics, knuckle joint presence. So all these are given. Let me just go through one. This will show you the video.

On the upsetting equipment. It is a gravity drop hammer. So this video is always connected to YouTube. Here in this virtual lab simulation. That is developed.

You can watch this video on YouTube as well. There is also a narration. When you are watching the video. Even though I am teaching this. I am demonstrating this laboratory.

I will tell you what is happening. If you play this video on YouTube. The developers have provided their own narration there. About what is happening. What the hammer is.

What the components are. And different simulations. When you watch. You will also see the narration. There as well.

So here you can see this YouTube video has come. If I play this video, it will show that the gravity drop hammer is working like that. And it is only because of the weight that it is dropping down. And different components are given on the left-hand side of that board: ram, dies. And wheel forging stock is on the right-hand side where it is played.

It is only a 1-minute 25-second video. This is a video on the gravity drop hammer. I will walk you through processes such as upsetting, extrusion, multi-step forging, rolling, and sheet metal. A wide range of processes are here. But I will only go through a specific few processes which are more commonly used.

Let me first come to the upsetting process, where you can see the theory about the upsetting process. What is the upsetting process? It is a free-forming process by which a billet or portion of a workpiece is reduced in height. Usually, a plain parallel plate is here. And the ASM Handbook 1988 is quoted, from which this definition is taken. The components, the equipment setup, the video about the generic equipment setup.

It is all given here about upsetting the generic formula of the upset strain and upset ratio, which is also provided. This is the theory about the upsetting process and how the metal flow happens. Because there is bulging here in the metal. That means you can see in the video when the upper die and the lower die are here: the upper die is moving, and the lower die is fixed. And this bulging is happening—how are the four things flowing?

And you can also see the mesh is a triangular mesh. What is the expansion in the mesh? And at what point are these specific nodes moving? So, this is the upsetting process. This is the billet.

This is bulging, and this is the product that has been obtained. And based on the die velocity, the metal flow rate changes. The properties of the products also change. Now, in upsetting, if I move to simulations. So, this is one simulation that is given about the forces—how do those travel?

For example, if I play this video in which the material is aluminium, zinc 5.6, magnesium 2.5, and copper 1.5. The height is 100 millimeters, and the diameter is 100 millimeters. The billet temperature is 300 degrees centigrade, and the die temperature is 250 degrees centigrade. The reduction in height is 50 percent, and the press is hydraulic. If I play this video, this is an upsetting process in which the lower die is fixed, and the upper die is moving.

So it is an open-die forging process, as it is studied as well. So it is extensively used for shaping, etc. This is all narrated there in the video. You can watch that. When the load is applied, you can see the color change.

Then, on the left-hand side, you can see this key of the color is also given. So the expansion of the nodes, you can see how the strain is happening. The color has moved to orange. It has moved to red color now. So it is reset.

And this is an axis-symmetric process in which only one part is simulated. So, to understand this, this video is provided. There is another video. If I play that. So, this process is regarding the force during the upsetting operation.

You can see. The metal-forming simulation is there. And here, you can see the graph that is showing the force. So, the metal is plastically deformed here. So, it is open-die forging, as I said.

You can see this is happening. Once the force is applied, you can see the change in the force that is happening. The forging force evolution during the upsetting process. How is the force varying here? You can see this graph.

The force is increasing. The red line is representing the force. It has come to maximum. So this was upsetting process. Let me just come to the simulation bench.

Simulation bench means it is showing what different parameters. We can fix for this specific operation. For example, in the upsetting operation itself. You try to pick aluminium material with L by D ratio as 1.0 only and coefficient of friction as medium only. The velocity of upper die that is the speed of the die that is moving is 10 mm per second.

And we would like to see the simulation for hot process. Let me submit this. There is a video and there is also the subtitles of the videos are given below itself. The video shows the upsetting operation taking place during hydraulic press. The initial billet of aluminium L by D ratio 1 is taken hot and upsetting operation medium friction for bullet.

And this is shown on the top at the end of the video for this medium with an upsetting forging process. You can see this here if I even turn this to full screen mode. You can see here at the top the upsetting process: hot forming, friction medium, L by D ratio 1, die velocity at 10 millimeters per second. Whatever we selected is presented here. I exit the full screen mode and will just play it from the middle itself.

You can see how the forces are going—this is the force in tons and how it is varying. So this is represented here. This is the 50% deformation that is represented in this simulation. This is the simulation way this hot metal forming is presented here because it is better to understand the forces at play. On the left-hand side, you can see this color representing the equivalent strain.

How the strain is happening. So this was the simulation bench for the hydraulic press. Now comparative simulations are also there. Effect of different materials, effect of friction, effect of temperature, effect of ram velocity. For example, if I try to see the effect of different materials.

You can see the simulation is showing the simulation of different materials. So this is if it is in the video name as case one. So the top left quadrant here is copper. And the top right is aluminium, and we have titanium and steel on the bottom left and right respectively. You can see how the forces are varying in different kinds of materials.

This kind of comparison is also given here. So titanium, as you know, is a very hard material. So the forces would be very high here. The simulation is also given here. Then we have the applications here for alloy wheel, brass forged part, forged piston, mud guard, and pattern making.

There is a self-check quiz as well here, as it was available in almost all the simulations that we studied. Here in this quiz, the questions are there. So self-check quiz for the upsetting process. The first question is: the virtual simulation lab website shows information about which manufacturing process. Obviously, it is going for metal forming, the contribution of Indian forging industries.

And global forging market in percentage is it is given 5% here. The main purpose of upsetting operation on billet is to, the main purpose is to increase the diameter and decreasing height. The number of presses shown in upsetting process module are, 4 presses were shown, this is question 4. Question 5 is L by D ratio used in interactive bench of simulation. There were 3 L by D ratio of options available, 1.0, 1.5 and 2.0.

Velocity of upper diagonal simulation for upsetting operation is, this is just to make sure that whatever we have done. We have done that and we could just recall the things. It was 1 mm per second and 10 mm per second. The material which is not used in simulation of upsetting operation. Here titanium is used, aluminum is used, copper is used, lead is not used here.

In upsetting operation which die moves, upper die moves. Which process involves increasing the cross section area by pressing or hammering in a direction parallel to the original ingot axis. What is this process? It is upsetting process. Upsetting process is an open die forging process that we submit.

Once I submit, they give me, okay, this is your answer. Column 2 and column 3 are the correct answers. In total, we have scored 10 out of 10 points. And this is the simulation of the upsetting process. Similarly, I will keep going through simulations of different processes.

For that, first, we have to return to the home button. I will click the home button here. I will click the home tab. It will return to the home screen. So I will again select another process.

For example, I will now select extrusion in processes. The generic simulation about extrusion is given here. So, what is the hot extrusion process? You can see a hot extrusion process is given here. It is a metal forming process where a heated billet is forced to reduce its cross-section by friction.

So, the first video is about the hot extrusion of a pipe. You can see in between we have a mandrel that allows only pipe material to come out. And the right-hand side video is about the complete rod that is not hollow inside. So, these are the two simulations, and different forces are also given here. You can go through the processes here.

The simulation part I will come to. So, this is generic—how the extruded bar comes. So, this is a billet. It is reduced in diameter, and the length will increase. So, metal flow is a steady-state extrusion process that is given.

So, forward extrusion and extrusion load, peak load, friction load—everything is given here. Then we have the optimum flow. Process conditions: maximum extrusion load is increasing; maximum extrusion exit temperature is decreasing. In between, at the intersection point, there is an optimum process condition—this is regarding extrusion. Let me come to the simulation of extrusion—comparative simulation.

It will compare solid and pipe extrusion. So if I click here, it has given a video where on the left-hand side you will see the solid extrusion, and on the right-hand side. There is a pipe extrusion. So the die angle is specified here. 60 degrees is given here.

The speed is 1 millimeter per second. The extrusion process for aluminum is given in both of the halves here. The graph between extrusion force and pilot height shows the extrusion forces are higher during pipe extrusion than the solid shaft extrusion. So here, temperature variation in the billet is being shown.

Temperature variation can be seen by the color. The red region shows the maximum temperature. It is also given here. The red region shows the maximum temperature generated at various cross-sections. One-fourth of the solid shaft is being shown on the screen.

So the inside view is clear because the shaft is axisymmetric. This is extrusion. So let me do a comparative simulation of the effect of temperature on the extrusion or in the extrusion process. This is a video showing the three parts. The top part is the pipe extrusion.

The left half bottom is also pipe. The right half bottom is the rod extrusion. In the upper half, the ram velocity is 1 mm per second, as given here. Friction is 0, die angle is 60 degrees, and it is specified that there is no friction in the cold extrusion. The lower left part has a ram velocity of 1 mm per second.

The die angle is 90 degrees, and there is no friction, as also assumed here. On the right-hand side, it has a 45-degree die angle and high friction during this hot extrusion process.

This is a comparison between two cold extrusions and one hot forming process. So, this is cold. The top and the left bottom are cold.

The right half is hot. So, the comparative change in flow and speed that you can see here. So, as the pilot height reduces, the force required for the extrusion of the pipe increases. So, this is the temperature. This colored sheet shows the temperature.

So, this is the extrusion process. So, there are certain applications, for example, in seamless pipes, in pipe extrusion, in turbine blades, in caul sticks. And there are certain special cases, certain cases of extrusion for different variations in speed, in the type of extrusion that you pick, hot and cold. The types of materials given here that you can walk through, and a self-check quiz, I will now come to. So, which country has the maximum contribution in the worldwide forging industry?

Europe. The types of extrusion processes involved in metal forming are certain types of extrusion processes. Four types are given in this theory presentation that is shown in this virtual simulation setup. The parameter which separates the cold forming process from the hot forming process is the recrystallization temperature. Below the recrystallization temperature, it is cold.

Above it, there is the hot forming. How many types of presses are shown in the extrusion process module? I have worked through 10 different kinds of presses here. The force acting on the workpiece during the extrusion operation is: what is the force acting? Obviously, it is a compressive force.

I am zooming it out. The simulation bench of the extrusion process for aluminum, the velocity of the RAM used. This is just to recall whether we have used the right conditions or not. It is 1 mm per second and 55 mm per second. The die angles used in the simulation of the extrusion process for aluminum are.

I can't recall; let me pick. It was 60 degrees, maybe answer A: 45 degrees, 60 degrees, 90 degrees. I'll pick 60, 10 degrees, 45. Let me pick a wrong answer as well. Then we will see what happens. The metal extrusion process is generally used for producing uniform solid sections and uniform hollow sections. It helps to produce both.

For successive extrusion, the metal should be ductile, malleable, plastic, and tough. It should be plastic. The extrusion chamber, die, and ram are generally lubricated by vegetable oil. So these are all questions. I will not walk through all of them.

So there are 18 questions. If I mark some of the questions and miss some questions, what will happen? What will happen? I will submit the result. Only the questions that I have marked—1, 2, 3, 4, 5, 6, 7, 8, 9, 10—12 and 13—only for those will the answers appear.

That means to understand the right answer, you should mark it; you cannot leave it. If you leave it, the right answer will not be shown; this is designed this way. So it has given a score of 9, meaning 9 answers are correct. So the answer that is not correct is just marked randomly.

This is 45, 60, 90 degrees, the correct answer for the triangles shown in the simulation. And 211.2 millimeters and 157.5 millimeters were the correct answers for questions 12 and 13. This was the extrusion. Again, I will come home and then proceed to another process. I will pick the multi-step forging process.

Multi-step forging: the first step is to increase the diameter to make a cup or so. The second step might be bending from the top. The first step could be transforming the shape from circular to hexagonal. The second step could be making holes in it.

So, this is multi-step forging. Let me just go through the multi-step forging. So, there are certain steps in multi-step forging which are given. For example, I will just pick equivalent strain forging force. If I pick this, you can see

How is equivalent strain being shown here in this forging? This is a raw material here, and you can see a triangular mesh here. To develop the CFD module here, this mesh is generated or created. So, I'll play the video, and you can see the die moving. The video shows the upset stage, which is step 1, where it is upset, followed by a blocker stage, which is step 2. This is the second stage, and in this blocker, it will give it the final shape.

So, this setup is given on the left-hand side, and the right-hand side shows the forces which are happening. So, the blocker die, you can say, in step 2 is bringing it to the shape that is required finally. So, this is a graph between the upper die versus pilot height in two successive stages. This is what is shown here. So, these are the steps in the multi-step forging.

Step 1. Step 1 is the upset stage, and step 2 is the blocker die final shape-getting stage. Now, in multi-step forging, certain other steps can be seen from the front and the top. You could also view how it looks from the front and from the top or how it varies. In step 1, you can see it is only changing the height, which means upsetting is happening.

In step 2, the front view of the workpiece is being deformed. This is the blocker stage. It is being deformed from the edges, as you can see. This is the front and top view of the simulation. It is changing shape.

This is the second stage that is going on. This is step two. It has come to almost the final shape. Again, I will walk you through the video. Step one: air upsetting is happening.

Only the diameter is being increased, and the length or height is being decreased. And this is how the forces or the strain are happening. Now, step two: the blocker is trying to bring it to a shape. You can see around the edges, the forces are maximum where the contact with the blocker die is there. And in the middle, some changes are also happening.

And from the edges, the forces are transferring inside. These are not forces. It is actually a strain, how it is going. From the edges, it comes inside. And from here itself, as you can see, a circle, a strain is extending out.

So this was multi-step forming; there is such an application. For example, in wall forging, in hubcap development, in the heading process, in ball pin hammer, certain different applications are there. For example, in wall forging, I will just play this video very quickly. So, there is a simple puppet wall being forged here, in which you can say first this is the billet. The first step is you get into this shape.

The second step is you get into this final shape. You can also fast-forward the video just using the YouTube tab here. I am trying to play it at 2 times the speed. 2 times the actual speed. You can see.

The first step is this is being formed. The right hand side is swinging and the left hand side is swinging with the complete item. The second step has now come. It is a blocker step that will turn the top of the valve into the required shape. That is the fourth product will then be produced.

It is changing the shape. This is the application in valves. So let me come to this self-check quiz. The number of steps in which designing of a forming process can be divided. They could be multiple steps that is shown in this theory or five steps.

Which of the following product is not manufactured by forming operation? Fasteners can be developed, hand tools can be developed, crankshaft can be developed, lathe, pad cannot be developed. Generally, in metal forming, the small components are being developed. The large components would need separate presses or so separate set of workstations. In the multi-step forging, for example, I showed you the example of valve.

In the single forging press, using two steps, this is being developed. It could be more than two steps. Three or four steps could also be there. But in a single workstation, using different kinds of die designs, we can develop. That is how it is developed.

So the lathe bed is not developed using the forming operation. Which of the following is an advantage of forging? Surface finish is generally not great. Low tool cost, low tolerance, improved physical property. That is one of the advantages.

Which of the following may not be the variable that affects the metformin process? So here, among the given variables, the surface luster is not significant or does not affect it. In forging operation, fullering is done too. Fullering is a process that is done to upset the materials. The process of removing the burrs or flash from a forged component in drop forging is called swaging.

Which of the following materials cannot be forged? Wrought iron can be forged. Cast iron cannot be forged. Mild steel and high carbon steel can be forged, but cast iron cannot. The answer is a forging defect due to hindrance or smooth flow of metal in the component lab where it occurred. So, when I walk through it, it occurs due to the shrinkage allowance that was inadequate in wall forging simulation of multi-step forging. The number of steps required for wall forging is two steps. You just walk through the wall forging simulation process.

In the wall forging simulation for multi-step forging, the material of the billet was there. Let me submit. So, I have gotten 10 points from the 10 questions, and these are again our given answers and the correct answers. I will come to the home tab once again. Two more processes I will walk you through.

A very important process here is rolling because we have studied rolling extensively in the 3D classes as well. So, this is hot rolling and cold rolling. How does the rolling process work? So, we have a two-high mill roll. We also have multiple high mill rolls as well as a three-high mill.

And this is ore high mill, this is a cluster roll mill, the continuous rolling process. Planetary mill is also there, multiple rolling systems are being shown here. And it is a transverse rolling process that helps to develop the veggies. They tell us to develop the components with the varying radiuses as well. This is a transverse rolling process.

So, shaped rolling sections are also there in which specific shape could be gotten in one go. For example, railway lines are also produced using the rolling process as well. So, let me come to the types of the rolling process. It is showing ring rolling, thread rolling and wedge rolling. Ring rolling is a specialized type of metal forming operation which reduces the thickness.

That is the cross section and enlarges the diameter of the workpiece by squeezing action as it passes between the two rotating rolls. So, this is ring rolling process. You can see there is a mandrel, there is a ring and there is a lower and upper conical parts here. So this is how the ring rolling process is working that we have seen. Let me come to the next set of thread rolling.

Thread rolling means we try to produce threads on a rod. We can also have knurling on the blank as well. Knurling is also done. Certain processes like these are performed here. So, there are four main types of thread rolling, named after the configuration of the dies: flat dies, two-die cylindrical, three-die cylindrical, and planetary dies.

So, these are different kinds of the thread rolling process. You can see the upper die and lower die, where this shape or profile matches the type of thread required. The size of the thread, the angle of the thread—everything is incorporated into the die design on this surface. So, the two-die cylindrical thread rolling process, three-die cylindrical thread rolling process, and planetary die thread rolling process are all shown here. Let me now show the simulation of thread rolling.

Thread rolling: three kinds of simulations are shown—using flat dies, using two rolls, and using a set of three rolls. I will now walk you through the simulation of thread rolling. And I will focus on showing the equivalent strain here. So, you can see here—if I play the video—this simulation demonstrates the finite element analysis of the thread rolling technique using two reciprocating well-grooved dies. Well-grooved means it is designed or grooved according to the required thread size.

So we note that at the point where the roll first comes in contact, the maximum strain is generated. You can see here the maximum strain is generated at the points which are coming in contact. So it slowly fades into yellow, then it comes down to green, and finally into blue color. So the legend is showing the strain that is happening in the initial contact; the strain is high. Then slowly, the strain becomes lesser.

So here, up to 500 mega Pascal of pressure is used. This is thread rolling. Quickly, you can go through thread rolling and different kinds of rolling. Here, thread rolling processes show the different kinds of simulation setups in thread rolling. Other than thread rolling, you can select maybe other rolling processes.

And you can keep walking through the different kinds of setups. So this is how the rolling process is happening here; the force in tons is given. And with respect to time, how the force is varying. It is showing in the beginning the force is high, then the force is reduced. So that is why the strain was also higher in the beginning.

That I showed you in the previous video. So I am coming back to the generic rolling once again. Then I will try to review my knowledge in the quiz. For example, the first question is: Alligator ring is the defect that arises in the process of rolling. The smallest rolled product that is there is a slab.

The velocity of RAM used in the simulation. Different questions are again given. I can pick some answers here. I am just picking very random answers because the final answers you can see in the final result here. I am just picking some answers, and I will click the submit button, and you got the answers here.

The answers which were not correct are corrected in the third column here. You can see here. You can go through the self-help quiz here. These are very basic simulations that show you the varying temperature, varying strain, and varying forces which are there. Now I will go through the one last process, which is sheet metal working.

Sheet metal working, as we studied in the theory, involves one sheet in which shearing, forming, and finishing processes are carried out. So, you can say this is a punching operation. After the punch operation, blanking is performed on the worksheet. We take the blank out of a sheet, perforate it by punching multiple holes, part the sheet into two or more pieces, and perform notching and lancing. All these processes are part of sheet metal working, including bending the sheet as well.

Sheet bending machines and setups are used, where tension is applied at the bend area. Now, let's discuss bending operations in sheet metal. Let me select a U-bend punch. In this bending operation, you can see a punch coming from the top. This is a U-bend, and it is being bent here. I will replay it to show how it looks when it first makes contact. You can see the forces increased significantly.

In the end, the force would have one big peak and then decrease. This is a sheet metal bending simulation. Here, the cross-section of the die is rectangular, and the bend produced is a U-shaped bend. This is a generic bending process. Another bending operation I can demonstrate is V-shaped bending using a punch.

So here, a V-shaped bending punch is there with the sheet that is taken as a 1 mm diameter sheet. The punch velocity is 3 millimeters per second. It is given here. The theory is given here. The maximum punch force is 0.6 ton.

That is given here. So this is also a bending operation. You can also now go through the self-check quiz in sheet metal and try to find the right answers. So this is generic. You can pick any of the operations here in processes, any of the processes, or any of the operations in each of the processes.

Certain simulations and cases are given. So this is the virtual laboratory simulation on metal forming. Just a quick demonstration I have given. You can walk through any of the simulations, and certain help videos are given by different laboratories across the world. Just walk through them.

If you have any queries or specific questions, you can post them in the forum and also in the live sessions of this course when we meet. You can ask them there.

Thank you.