Principles of Metal Forming Technology

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Lecture – 01
Introduction to Metal Forming Technology

Welcome to the lecture on Introduction to Metal Forming Technology. So, hi friends I am Dr. Pradeep Kumar Jha, I am associate professor in the Department of Mechanical and Industrial Engineering IIT Roorkee and, I affiliated this course for you that is Principles of Metal Forming Technology.

So, this is the introductory lecture of this course this is lecture number 1. And in this course we are going to talk about the different aspects, related to metal forming technology. We will talk about the theories behind it, different types of metal forming processes, then you have different types of relationship, forming diffraction all that during this course.

So, we will start with the introductory lecture of this course. So, metal forming process as you know they are used for plastically deforming work piece to desirable shape and obtaining optimum mechanical properties. So, why there is need of forming, we have been knowing about different types of manufacturing processes and forming is one of them. The other forming processes or other manufacturing processes are like casting welding machining all that and there are other varieties.

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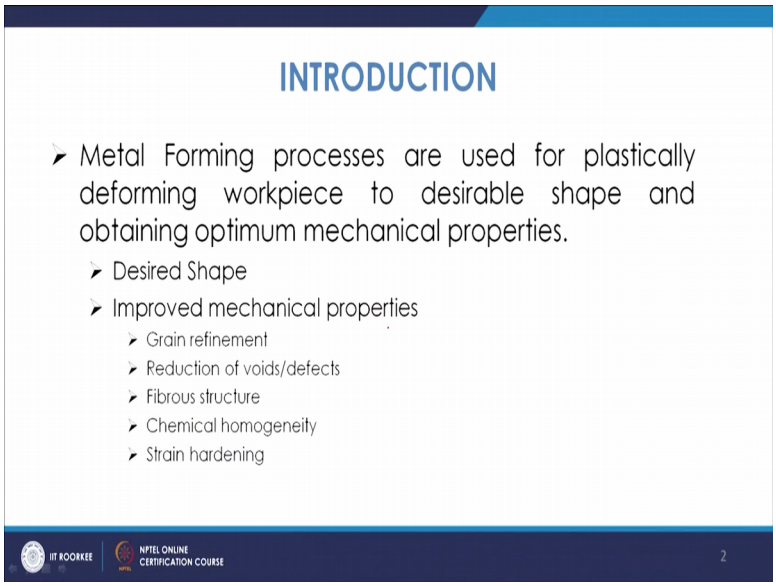

Where we use powder metallurgy and other things, but why forming is so, important. The thing is that first of all we must know that what is that forming. So, that is nothing, but your shaping the material to a particular desired shape. Now, can that be possible by other ways. So, when we talk about any engineering process, we talk about the alternate routes, we talk about the economy of the process.

So, first of all talking about the alternate routes so, if suppose you have to form any material and, for suppose you have to reduce its dimension. So, that can be possible by many ways first of all the casting so, you can cast it of smaller size. But for that you have to further go and replicate all the processes like you have to make it smaller pattern, you have to make it smaller mould, then further you have to melt and then you have to put it.

The further easier process, or easier mode may be machining, where you are keeping the job on a machine on a lathe machine, or any other kind of machine and, then you are removing the extra materials by that also you can think of removing the extra materials.

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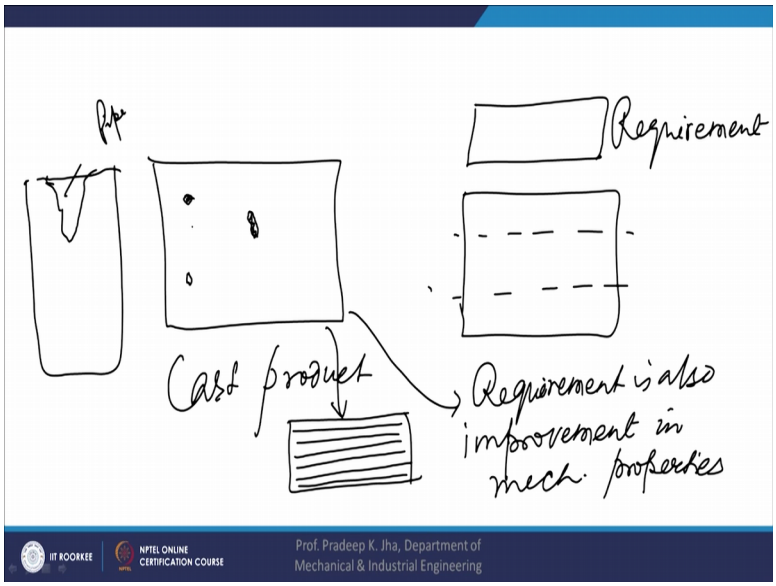

So, suppose you made one piece by casting of this dimension. So, this is your cast product. Now, you need a product of this type so, you need it. So, requirement is about this size of product. So, you can you can go for casting as we discussed that you can go for further the process of casting and, then you can make a smaller mould, you can have a smaller pattern and then you can make it.

The next process may be by machining. So, you can remove this you have larger size of product, you remove this much of portion from top and bottom. And then you can get the this size of the product. So, that is by machining process, but when only thing is I mean in these cases you are converting the size of the product to the final shape, but what happens that when you require that its property should also be modified you require that this product requirement may be. So, your requirement is also improvement in mechanical properties improvement in mechanical properties.

Now, the thing is that this also can be done by some of the other methods you can go for the casting of this sample of smaller shape and then further you can go for the mechanical property enhancement by other routes. Like you can go for heat treatment and other ways, but the thing is that again heat treatment may not give you that kind of property enhancement.

So, the thing is that when you need a specific type of properties, specific type of you know good qualities maybe some properties in certain direction it is quite high or in fact,

you want to alter the structure. So, you want to alter the structure to a fibrous type of structure, which has a very very high strength very improved property which has you know minimum of the defects in that.

So, in those cases you may have to go for one such process, where you can think of minimizing the defects having some properties which is very very good. So, what I mean to say that if we do the casting further the structure is not going to change much, the same type of microstructure you are going to get with some modification certainly. Because, if you are changing the size there may be some change in the microstructure may be at the surface, because of the different cooling rates experienced. But then overall the property may be identical. Similarly if we do by machining then also you are not going to change much may be wherever whatever properties was there in the middle it will be there.

But then if suppose you wish that you should have the material with very high property mechanical property, you should have a fibrous structure you should have very good strength in those cases you will have to apply the forces, first of all this dimension is short. So, you have the short dimension now how to short in the dimension. So, we discussed about the different methods. So, in this case you apply the forces and you trying to convert the size to smaller one. So, in that process you apply the force, then if you know control the dimension in one direction, then in other than it will be changing. So, if you are so, because of the volumetric constant rule. So, in that case you can alter the you now dimension.

The thing is beneficiary part you have in your cast sample there are the chances of certain type of defects. So, you have something like blowholes, you may have something like shrinkage cavity cavities. So, you have may have pipe formation, where we talk about the larger ingot structures you might have seen the large ingot type of casting, then what we see is that in the middle you have a pipe type of structure. So, this is these are the pipes. So, pipes are formed in the casting because of the shrinkage which occurs so, mainly because of the central and shrinkage.

So, the thing is that when we talk about other routes, you have our especially the casting which is the mother of the manufacturing processes, you have the chance of having such defects. But then when you are forming when you are applying the pressure from both

the sides, in that case what happens and when because of that you this dimension goes on decreasing in z direction, then what happens that these points of discontinuities that is defect, or the pipe or so, or shrinkage they get welded. So, they will be slowly disturbed they will be slowly disappeared.

So, in that case the property of the material get is improved. Also on the process I mean beneficial in the sense, that when you are strain hardening the material, when you are straining the material at lower temperature side. In that case because of the strain hardening effect the materials you know strength is increasing. So, this is again I mean that is why it is important to know that what kind of property you want, if you simply want to just decrease the dimension you can go for the routes, but if you want specific properties, if you want very less porosities very good quality you will have to have alternate route and that is achieved by the forming process.

So, what we say is that it is used for plastically deforming work piece to desirable safe and obtaining optimum mechanical properties. Now, plastically deforming so, as we know that whenever we apply force there will be the formation. So, force is applied will call deformation, but every deformation is not permanent, deformation is either you know recoverable or non recoverable. So, when we are applying the force, there will be certainly some deformation, but that deformation may not be permanent so, that is elastic deformation.

Then there is a limit that is elastic limit and when we deform after certain limit, then that becomes the permanent deformation and that is a plastic range of deformation. So, in that case you have a permanent set, or permanent deformation which is there in the material.

And in the case of metal forming we are deforming in the plastic range. So, that the deformation what we get is permanent. So, one thing is that so, what we say is that there are two things one is desirable shape. Now, the safe we discussed if we have to have certain shape, that we have to keep that in mind and we have to move our processes in such a manner that finally, we get that shape.

But along with that you have the improved mechanical properties. Now, improved mechanical properties means the properties which we get there are the defects, which we get normally in the cast samples, now these defects are not at all desired in certain components. Suppose, we are taking the example of the automobile, or you are taking the

example of you know crane hook or so, so in such cases you require a very good high strength with minimum chances of failure, because of any kind of structural discontinuity or defect or so. So in those cases you cannot take any you know chance and, the most material must have very very high strength.

So, in those cases you need to have the process in such a manner that those I mean chances of defects are minimum. Now, the properties can be improved by many ways by so, what are those methods by which these properties are improved. So, the forming process in general, what it does it may go for grain refinement, what happens that when we form the material and specially at the higher temperature range.

In those cases what happens that after certain temperature after recrystallization temperature, when we are finishing the forming process. So, after that temperature your birth of new grains starts. So, that basically gives in the grain refine structure. Many a times when we fabricate material, it may have lot of stresses, or once it is cold weld material lot of dislocation density is increased you have dislocation sites are there, imperfection sites are there.

So, basically these are the points where form the nucleus in the starts and, if you go to the hot working range in those cases normally you have formation of new grains. So, decrystallization crystals reappearance so, that is your that leads to the grain refinement.

Similarly, you have a reduction of voids or defects. So, that is what we discussed that when we do the material, when you fabricate the material by normal casting process. In those cases it is likely that normally in the casting processes, slightly that you have the defects like blow holes or pipe formation, or shrinkage cavities or so.

So, now these are basically the source of defects, which alter or which hamper the mechanical properties. In those cases basically when we go for when our image that, we should not have such defects in the forged product; So, when we use the forming process, when we apply the pressure from both the sides in those cases these voids or defects they are minimized.

So, the position, where there was no metal because of the shrinkage. Now, because of a the proximity of the grains from both the size approach in each other then ultimately they

meet. So, this way wherever you have the defect they are disappeared. So, wherever you have voids they get disappeared.

So, this way once your voids and defects are minimized once your blow holes are welded together, in those cases ultimately the property get is improved. So, this is one of the main advantage of the this metal forming process, then the fibrosis structure. Now, this is also one of the important point, which is there in the case of forming.

Now, you can see the fibrosis structures, if you look at many of the materials used has fibrosis structures and, what is seen is that it is very difficult to cut the fibers difficult to cut the fibers rather than to tear it. So, what happens in many cases you prefer to have a fibers.

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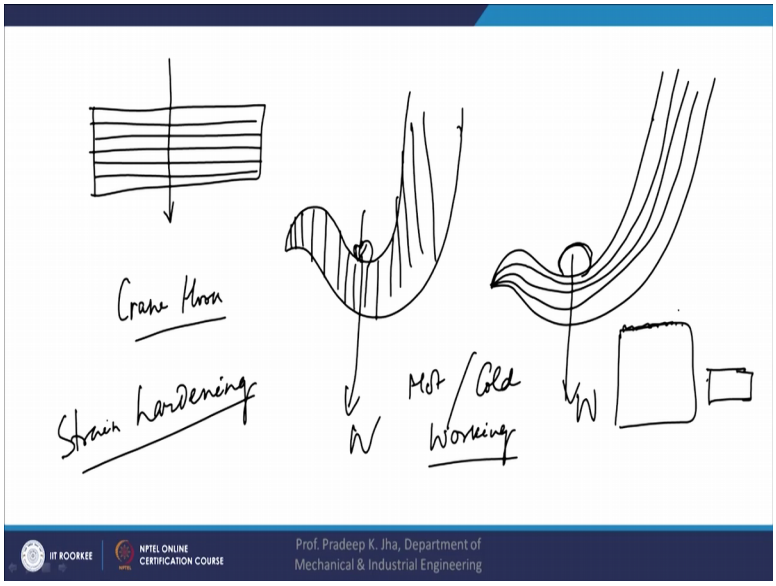

So, once you have fibrosis structure or grains oriented along certain direction. Then when you are trying to have pull it like this, it will be certainly resisting you know large forces, or many a times when you are trying to cut across the fibers, that is also very difficult.

So, you need to have these fibrosis structures to have more and more strength, a typical example is the example of crane hook. So, what happens that you must be recalling that the crane hook is of this type.

Now, in this crane hook there may be two structures, one crane hook is like this and, then you may have the crane hook like this. Now, suppose why in one case your structure fibrosis structure is all fibers or grain so, you wants you have made it is like this. And in another case you may have the fibers go like that. So, now, the thing is that when we are using this grains what happens that your load is from here, and this way the load is being applied.

Now, the thing is that in this case if your fibers are oriented like this and, if you are applying large force here, then there are quite a good chance of basically that fibers getting teared a part. And in that case there will be failure of this part and that will lead to catastrophic.

So, then this may be so, this structure may be because of the cast component, or improper fiber direction and, or you can cut from a cast sample you can cut it in that case there will not be fibers and you will have you know no continuity of the fibrous line and, the fibers orientation may be like this.

In that case there is chance of failure while, if you apply the force in this type of fibrous appearance, then it is likely to resist more and more to the forces; So, normally it is kept in mind that what way your material is going to be applied.

And accordingly we adjust our processes of forging. So, that we try to have a fibrous type of a structure. So, in that case once you have a fibrosis structure and, also we see that there is no discontinuity of the fibers, fibers are not cut in between in that case your the continuity is broken and, the property will certainly be you know hampered.

So, those are the you know situations which are to be looked into and, this way once you have the fibrous structure, this is achieved by the forming process when you are forming it by applying the compressive forces, or the type of forces and you are trying to orient the grains in particular direction and then you have fibrous appearance.

Then this way the property is improved, then you have chemical homogeneity. Now, many a times when we do the forging, you will have redistribution of the chemical elements and, in that process the chemical in homogeneity which is there. Suppose you have a many a times your certain you know impurity elements are there somewhere segregated, some something some of the thing things are not properly distributors of the

alloying elements or so, or many a times you have also the residual stresses which are allowed inside.

Then when you go for forming in your heating at higher temperature that is removed, then the there will be proper diffusion at that higher temperature side. And then in that case you will have redistribution of this stresses, especially when if you talk about the iron based alloys. So, when you go to that range you go to austenitic range for the forming process basically hot forming process.

And in that case you will have a the redistribution of these chemical elements, if any or in that case your chemical homogeneity is achieved in the forming process. The point which we discussed about the forming is, one is the desired shape and other is the mechanical properties and, one of the mechanical property which is normally of importance is it is strength ductility or so.

Now, the thing is that certainly we can get the improvement in the properties, because of other type of you know events also like grain refinement reduction of voids fiber structure or chemical homogeneity, but then strain hardening is a process, in which because of straining the material becomes more and more you know a strong.

So, in that what happens that, when we increase the strain on the material in that case so, you must have heard about the dislocation density is increasing, because of the cold work. So, once you increase the cold work, when we are forming at I mean below certain temperature in that case when we are increasing the amount of cold work the dislocation density get is increased and, the material becomes harder and harder.

So, basically when we form the material especially cold forming, the material's strength becomes higher and higher. So, that is another you know purpose which is a very important factor, which is adopted for the forming process. So, this way when we so, strain hardening is the mechanism and, when strain hardening when we increase the amount of cold work. The material gets more and more hard.

But certainly we have to know that what should be the amount of cold work, because as you go on increasing the cold work, then the materials hardness will increase. And if it is too high then that will turn towards brittleness. So, the material may be extremely brittle

so, the ductility may be too less the metal material may be brittle and may be of very less use for engineering applications.

So, strain hardening is experienced mostly in the case of cold forming and, you must have seen all the smaller you know thin sheets of the metals like iron sheets, or other corrugated sheets. So, they all are cold work even after I mean when there. So, think they have a good strength it is all because, they are strain harden and then in that case the hardness is improved. they are many forming processes like wire drawing or so, where this principle is used, when we try to have the wires of different types of hardness.

So, basically what we do is we control the cold hot working and cold working, to achieve the you know degree of you know hardness either it will be whether you want stuff or soft type of material all you want extremely hard material. So, that depends upon the temperature and because of a temperature basically you differentiate as hot working as well as cold working.

So, when we talk about hot working, then we talk about forming to a temperature which is more, than recrystallization temperature and when we talk about cold working, then it is nothing, but forming below certain temperature that is recrystallization temperature. So, what happens that again depending upon the need, we can go either for hot or for cold working; so, hot or cold working.

Now, the thing is that you have two objective, when you have to deform to a larger extent, you will have to go for hot working. So, the material from here to hear it cannot be done by cold working.

So, it has to be done by hot working in stages because, when we heat the material its ductility is becoming more, it is you know its strength becomes less and you know that way you are trying to reduce the dimension of the material, but as the temperature goes on decreasing, in that case it is a strength becomes again further higher and you require very large, or capacity equipment to further reduce the dimension.

So, when you have to decrease the dimension to a larger extent, you go for hot working, or else you go for cold working. There are limitations basically of the hot working as well as the cold working. So, they are basically since being of based on temperature, you have the different you know the parameters, basically to define them whether you should

go for hot working, or cold working like when you go for hot working since you are working at very high temperature, there are chances of scale formation.

And because of that the surface appearance may be may be that, once you are surface finish may not be appropriate, you cannot control the dimension, And then another disadvantage is that, when you are further going putting it into the in between the dies, then there maybe impressions on the surface.

So, this way scale pits are formed but then when you have so, for that also there are ways like you can do in the control environment, but then if you go want to deform the cold working, there is certainly limitation up to what degree you can do the cold work, because if you do more and more then material may get, there may be in brittleness induced in the material and the material may break in between.

Similarly, when we talk about hot working so, in hot working basically recovery and recrystallization; so, recrystallization temperature is the you know boundary above, which the hot working is defined and below which the cold working is there. So, in the case of hot working there is recovery. So, what happens that when the strain grains or a strained, further that that strain is released because of the higher temperature. So, there is recovery taking place in the case of hot working whereas, in the case of cold working recovery is not there. So, every time you are deforming the material get is deformed and larger amount of stresses are generated material is get is strain hardened.

So, this is how I mean depending upon the nature depending upon the final product what you want, you would like to go for hot working as well as cold working, for materials for every material you have different types of different temperatures at which they have to be formed. And normally this temperature is a function of the melting temperature. So, that way you do the hot and cold working, apart from that when we talk about the different kind of forming processes, you have different sets of forming processes depending upon what you want what kind of product you need.

And today when we have you know good requirement of materials, which must have very very good you know reliability, which has minimum where your minimum chances of error, you must use the optimum forming process to get the product with minimum defect. So, we will discuss about the different you know types of forming processes and, and also the fundamentals of the forming processes in the coming lectures.

Thank you very much.