Design for Quality, Manufacturing And Assembly
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Lecture-32
Quantification of Part Symmetry

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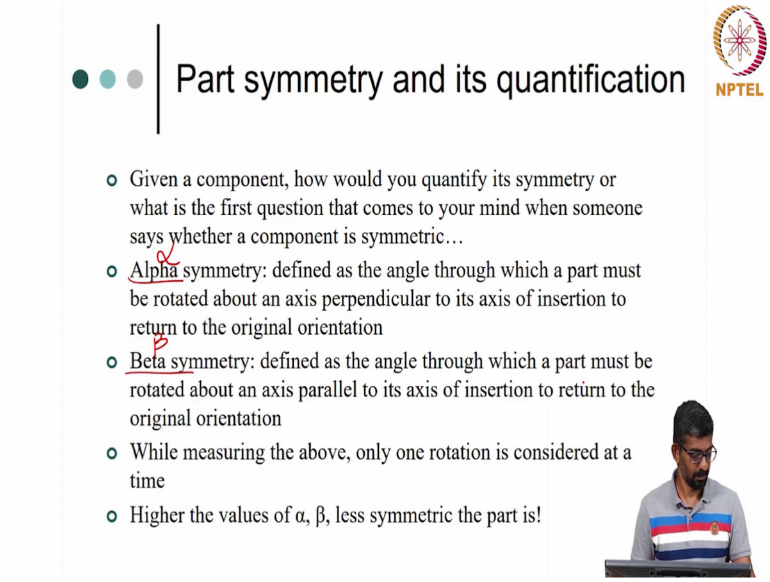

So, then we will go through a few guidelines on how to quantify these guidelines ok. And then we will not go through it will not be comprehensive what we discuss here we will go through few of them ok. The first one with that we discussed was the symmetry. If I ask you to quantify symmetry, how do you think you will do it or rather what is the first question you might ask me, I show you this and I am asking whether it is symmetric?

Student: (Refer Time: 00:48).

Sorry?

Student: Direction of symmetry.

Direction of symmetry, axis of symmetry something that you will ask ok, anything else? Correct, the answer is right. This is symmetry about which axis?

Student: X.

Sorry?

Student: X.

About x it is symmetric? Is it symmetric about x?

Student: Y axis.

Y? About y it is symmetric, about x it is not symmetric?

Student: (Refer Time: 01:21).

Where the x axis it depends, is that all?

Student: (Refer Time: 01:30), it might not be an exact cylinder.

Let us assume, it is an exact cylinder you are right. It is not an exact cylinder, but for the sake of discussion, we will assume that it is a perfect cylinder. From there you are able to see this is a cylinder right, we will say it is a perfect cylinder. So, one is along the horizontal axis, the other one is along the vertical axis, then?

Student: (Refer Time: 01:56).

Sorry?

Student: (Refer Time: 01:57).

What is that called? That what is that rotation called?

Student: Angular symmetry.

Sorry?

Student: Angular symmetry.

Angular symmetry, it is not angular symmetry, but you are pretty close. Conceptually you are right, but what is the word that is used?

Student: (Refer Time: 02:18).

Ok, but what is it called even in finite element we discuss this, what sort of a model it is? You take a watermelon and then you cut a slice, you remove it ok. And then you say I am going to take this piece and then I am going to do this. In a cad model, you will be able to recreate the watermelon, so that is what symmetry is right.

So, I break it and then what happens is I take the broken pieces and then I do it this way. So, it will create the replica about that axis. So, this the axis of symmetry was this axis, the axis of symmetry was this axis. And then so this is one axis of symmetry, this is one axis of symmetry. What else? If you see this part imagine that I can break it, in some angle here. And then I just rotate it, it will repeat itself, it is called axisymmetric about the axis ok, it is called axisymmetric model or you can call it radial ok.

He said angular symmetry correct, you can that is what I meant by the recall the watermelon, because you can create a small angular stuff and then you rotate it multiple times you will receive it. If you have a 30 degree sector, then you repeat it 12 times, then you will get the 360 reputation. If you have a 10 degree sector, then you repeat it 36 times, you will get it right. The idea is the axis of symmetry. So, we are going to define symmetry from that prospective.

Basically, the two things that you pointed out, one is the one we call it the alpha symmetry and the other one we call the beta symmetry. Now, but an interesting part here is you must remember that our assembly is decomposed into two activities. One is your handling and other one is insertion. In these activities where I am worried or concerned about symmetry is only in the insertion perspective ok. Because, the idea is if you can handle, then you can rotate. When this assembly when this symmetry comes into perspective, it is in the insertion perspective, ok.

So, we are going to define it with respect to insertion. So, what it says is you consider the axis of insertion. So, imagine this as a screw. So, I am going to screw, it like this. So, this is the axis of insertion if this is my screw, this is the axis of insertion ok. So, what alpha symmetry says is the angle through which the part need to be rotated about an axis that is perpendicular to the insertion axis.

So, this is my insertion axis this is my in insertion axis, the axis that is perpendicular to the insertion axis is this ok. Now, about this axis about this white sheet ok, what is the axis of symmetry or what is the angle is called the alpha symmetry ok. Now, imagine a screw hereok.

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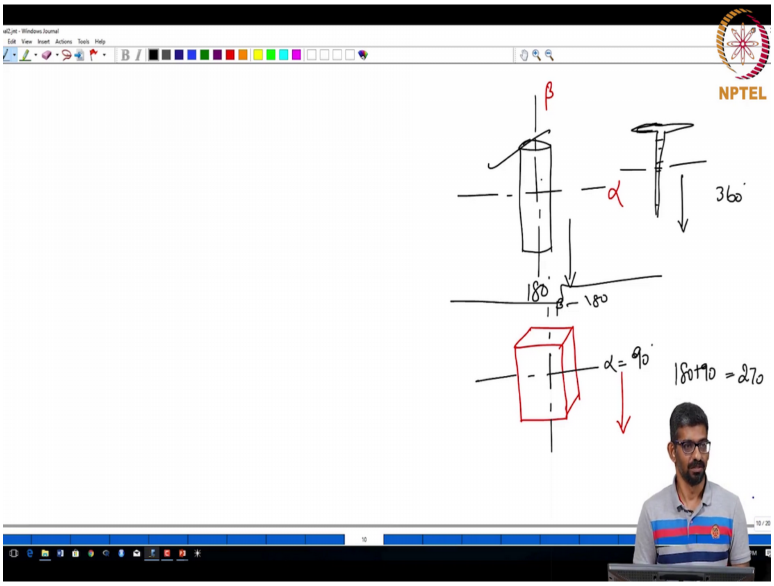

So, let us say that you have a you have a cylindrical part that you are going to insert into something that does not matter. So, this is my axis of insertion, then this is my axis that is perpendicular to it. Now, what alpha symmetry says is can you tell me about this if you are if you are going to like if you if you are going to take this guy and rotate this guy ok, how much angle do you need to rotate, so that I will be able to insert it again you understand.

So, this is the whole and I am going to try inserting it like this right. So, now this is my axis of this is my for the b a for the alpha symmetry, this is my axis right. So, I am going to rotate it 90 degrees, it comes towards me. You think I can insert it now, now I am going to rotate it this way 180, you think I can insert it now, yes provided this end and this end were the same that would not have been the case with the the screw that is why I did not take the idea. But, if you take the idea of the our the cylinder, you will be able to do that ok. So, what is the value of your alpha symmetry in this case would be180 ok. Whereas, you took the screw let us say if you took the screw, what is your alpha symmetry in that?

Student: 360.

It will be 360, you have to rotate one full time, then only you will get it, so it is going to be 360 degree you get the idea right. So, what you need to remember is symmetry is dependent on axis of symmetry if you want to quantify it, but in our case you are worried only from an insertion perspective. So, it is defined with respect to insertion. And alpha is the axis that is perpendicular to the axis of insertion.

And naturally beta will be your, beta will be what will be parallel ok. Beta is defined as angle through which a part must be rotated about an axis parallel to it is axis of rotation sorry, axis of insertion to return to the original orientation. What initially it was proposed is you talk only about one rotation at a time, because you can actually do two rotations multiple rotations also you can do.

But, only one rotation first one alpha, then beta like that you do you know cannot say like while moving this, I am also doing this. You understand what I am saying while moving this, you can also do this parallely simultaneously, but that is not what it says at a time you can only do one rotation that is what. Higher the value of your alpha and beta, less symmetric the part is correct, because for the screw we saw 360. 360 is greater than 180 and 360 is not symmetric, whereas the 180 had little bit of symmetry in that ok.

So, larger the value of symmetry lesser it is symmetric. How the same thing sorry the same stuff one second this is alpha and this is beta correct. Now, tell me for the cylinder what is your beta? Not anything 0 ok. So, now imagine this guy ok, his is angle of insertion is also like this. This is my beta. Tell me what is the beta symmetry in this?

Student: The phase is square, it is maybe.

It is not like a square right, it is a rectangle. I intended to draw a square, but it is a rectangle so it is?

Student: 180.

180 correct, it is 180. What about alpha?

Student: 90.

Alpha is 90, you get the idea? So, this particular part what is your symmetry metric? It is going to be 180 plus 90 that is 270. For this guy, it will 180 plus 0, which is 180 ok. So, naturally if you choose from a symmetry perspective, this guy is better than this guy ok. You can always say no I have a next door vendor, who can generate this at half the cost of this design that is fine.

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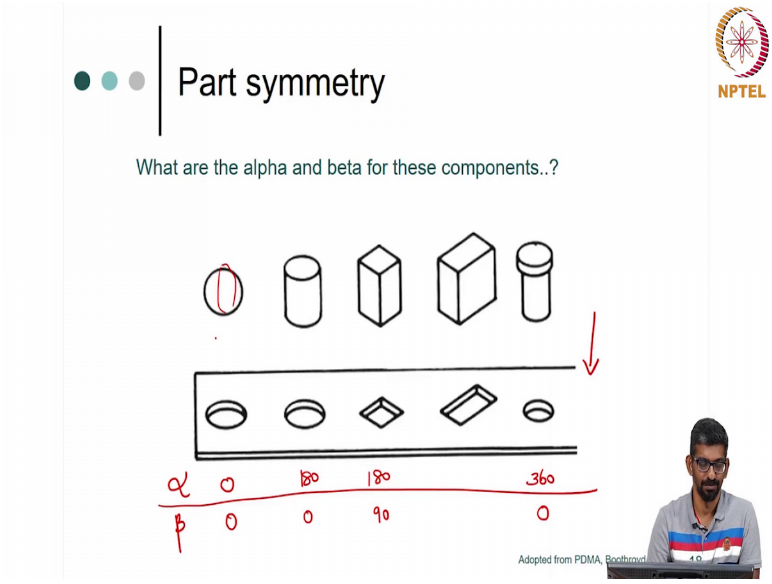

Irrespective of the design consideration, I will tell you what the value of symmetry is that is what the DFA says. Here is a question for you guys. Now, we will do this way. What is alpha for this guy, you can see for all of them the insertion angle is this way the insertion axis is this way, what is alpha?

Student: 0.

0 ok, what is beta? You can go this way ok. What about this one? Cylinder we have already discussed, alpha was?

Student: (180.

Beta is this guy is a square, we have discussed we discuss this one. What is this guy?

Student: (Refer Time: 12:40).

Alpha is 180. You can see how it is increasing ok. What about this guy?

Student: (Refer Time: 12:58).

It has a head here. So, I cannot do 180. It has to be 360, currently it looks like it is 0.

Student: (Refer Time: 13:16).

Part one and.

Student: (Refer Time: 13:24).

This one?

Student: Yes sir.

No, it is like a sphere I guess that is what I was thinking, this is more like a sphere, it is more like a sphere ok. You are just seeing from here it is actually it something like this, it is a sphere ok.

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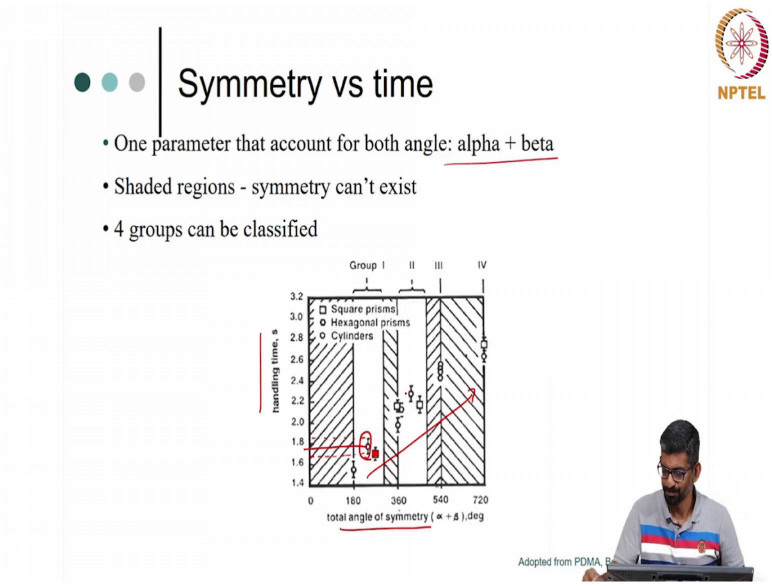

So, how because the end of the day, we are worried only about assembly time. So, this was the first step. We told that the difficulty in assembly can be quantified using this kind of guidelines one of them is symmetry, but how am I going to convert that into time. So, people did primarily this Boothroyd; so, primary bunch of guys, who tried to study all these stuff. So, what they did is they tried looking at the angle of symmetry, alpha plus beta in terms of degree and the handling time how long does it take ok.

So, the one parameter that can account is alpha plus beta, there were also other ways in which you can handle it. People say it should not be alpha plus beta, it should be alpha square plus beta square root, you can consider it depends ok. So, right now alpha plus beta is taken as an condition here. Now, what it says is in this particular graph they divided into four groups, group 1, 2, 3 and 4. What it says is wherever you see these guys, you know those are the square prisms, you know what a prisms right. So, it is a square prism cross section is a square.

And then there is a hexagonal in between there are these hexagonal prisms. And then cylinders, you can see the cylinders. How to read this graph, yes primarily you can say wherever you see the shades those combinations symmetry cannot exist. For instance, 0 it can exist correct and after that only 180 can exist. Alpha plus beta, you cannot have a 90, you cannot have a 45, you cannot have a 135. After 0, you can have only 180, you can think about it ok.

These are done, after detailed research ok. You cannot just have 90 degree, whereas the other guy you have 0, you cannot have that ok. So, wherever you see the shaded parts in those regions, the symmetry is not possible. You see the lines, so basically in zero they are not given anything ok. Whereas, for 180 it is there and between 180 and whatever this number is you know probably 270 ok. There is some combinations are possible ok. And then between 360 and less than 540 may be 500 some combinations were available. At 45 you can see this hexagons, these hexagonal prisms at 45 ok, it is a combination. I do not know maybe, it is 360 plus 180. So, you have these hexagonal prisms ok.

And then 720 both of them are 360, 360 ok. This is least symmetry that you can have, this is a best symmetry that you can have. Both alpha and beta needs to be rotated 360, then it will be 720. So, if you look at it, the amount of time goes in this direction. As your symmetry increases from 180 to 360, you can see the time has gone up. You see this small band around the value. So, basically what it means is this is your mean value and there are some bands, because it depends.

We are talking about manual assembly here how I would have done, you can get into these details and look at look at that. They would have probably stratified sampling, they might have had about 20 people, 30 people. And they would have given the all of them the same set of when they would have asked them to assemble it that is why, 20 different people will get 20 different time. And you take an average and then you take a band that is why you have this stuff here. So, it is not a single point value, but you take an average and you take a minimum and a maximum band around it.

So, now if you have this chart ok, you really do not have to go and make your part and see how much time it is going to take. You just look at the cad model, you know what type of a part it is you can find the alpha beta value from that you can use this graph to tell, what will be the handling time to assemble that part get the case. So, this is the first step that tells you, how you can quantify assembly time. And assembly time is a metric that is used to quantify a particular assembly.

If a particular assembly is time is larger than the other assembly, you say I would prefer this assembly or that assembly, because it is under the assumption that both the assemblies perform the same in terms of performance ok. It does not evaluated from a design perspective, you can always say a from a manufacturing perspective actually that is that is fine, but the deal is from an assembly perspective this has a better value ok. Any questions?

Student: What about complex?

Sorry?

Student: Sir, complex?

Any complex shape will only be within this. Someone in the class I do not know, so many years ago came up with the design like a like a football ok. Because, if you look at the football, it is hexagonal patches tied together. And in one particular case they showed that it need not be valid, this hashed region. They said there is a there is one more combination is possible, but I do not know whether you can manufacture today with me with 3D printing you can manufacture, but this was I do not no way back in 2012 or 13. Someone came up with this idea and then showed how this graph maybe there is a line somewhere in between ok. But, usually for all the manufacturable complex shape, this holds good, that is the idea.