Fundamentals of Electric Vehicles
Technology and Economics
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Lecture 34
Machine Design-Part 2

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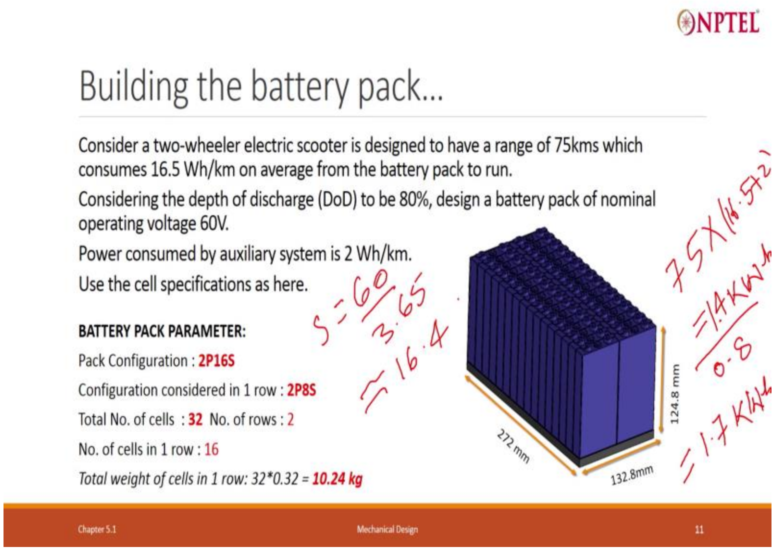

Moving ahead, what we have seen is a cell and cell form factor. We have also seen a building block where we know what is the current, what is the voltage. We also understood how parallel and series makes a system or a pack. Now, how to make a pack from the given cell? We have selected that cell. So, this is my cell based upon my requirement. Now, how to make pack from that? So, there is example here, consider a two-wheeler electric scooter is designed to have a range of 75 kilo meter which is common now a days. If you want to have a range you need to go for 50 to 75 or 80 kilo meter.

These two wheelers on an average consumes 60 16.5 watt-hour per kilo meter and from here it is coming in chapter 2 vehicle dynamics you go to drive cycle, you apply all the forces and then you find out what would be the energy required to run per kilo meter. So, we are not doing that calculation again, I am we are just taking a value.

Now, depth of discharge is 80 percent DoD 80 percent I want always my battery to be charge or discharge between 10 percent to 90 percent that means I will never discharge my battery less than 10 percent, I will never charge my battery more than 90 percent. So, my overall depth of discharge is 80 percent. Now, there are auxiliary systems horn, light, the new requirement in two-wheeler is that you have to always switch on your headlights or there has to be a light source always there.

There is a breaks and that consumes 2 watt hour per kilo meter. Generally, it is irrespective of kilo meter, but finally you when you look upon the range we need to convert all the energy into watt hour per kilo meter. So, what is our total energy consumption 16.5 plus 2-watt hour per kilo meter, so it is around 18.5 watt hour per kilo meter. For 75 kilo meter, what would be the energy required 75 into 16.5 plus 2, this would come approximately 1.4 kilo watt hour approximately.

So, to maintain a range of 75 kilo meter the pack energy is required is around 1.4 kilo watt hour, but then I have another condition the depth of discharge should not be more than 80 percent, so what I have to do if I have to find out the battery pack energy I have to divide this by 0.8. So, this comes close to 1.7 kilo watt hour.

So, now what we know is the capacity of the battery pack. How do we found; how do we find about the current requirement? So, there is a another information what is given to us, design a battery pack of nominal operating voltage at 60 volt. How does these 60 volts has come this has come from the prime mover from motor and controller. This require requirement is coming from the prime mover motor says I need 60-volt nominal that means there is some plus there is some minus because this cell is going from 3.65 volt 24.2 volt and the bottom side approximately 3 3.1 volt.

The simple you capacity by voltage will give you the current rating or AH of the battery or so from there, you can find out how many now you have a cell of 15 AH cells. So, if you see 1.7, so 1700 watt hour divided by 60 divided by 60 is coming approximately 30 ampere. Actually it is 27, 28 ampere.

Student: 29, 39

Professor: But my cell is 15 AH cells so either I can have a 15 AH or I can have 30 AH, if I put two in parallel, or I can have 45 AH or I can have 60 AH. So, 29 this is where the engineering decision has to be taken 29 AH I can go with 30 AH so that mean the two cells will put it in parallel. Yes, there is a question.

Student: (())(07:10)

Professor: we will come back to that one will will come back to the this is the answers I am still in question.

Student: (())(07:22) 28.4 into 30 (())(07:26) become 1.7 but voltage is coming as 58.4 (())(07:31).

Professor: I will explain you this one. So, the question is that he has gone to the answer of this battery pack parameter he has gone and then from the their question is coming why the voltage you are talking about 60 volt however, the voltage comes only 58.4, yes, I will come back to that in few seconds.

So, what we require is two parallel cells to make it 30 AH, however my requirement is only 29 AH and I do not have a cell which gives me 14.5 AH. So, here is the engineering decision, can we have two cells in parallel can be go to 30 AH yes we can go it does not make significant changes because 14.5 AH cells if you have to get it manufactured that would give take my whole budget profit everything this is available I can use this. Now the voltage requirement is 60 volt, how many cells in series? So, 16 by sorry 60 by 3.65 will give me the number of cells in series. So, what would be that? It would be slightly higher than 16.

Student: 16.4

Professor: 16.4, so if I have to calculate series that would be 60 by 3.65 so this comes approximately 16.4. Now, again now decision I have to take so that goes 16 in series or 17 in series because it is in between. But we also know, the cell voltage 3.65 is not a fixed voltage, it is a nominal voltage. It can go to 4.2 and it can come to 3. or 33.1 volt. why do not we use 16 cells where my lower limit when I talk about 60 volts, it is not always 60 volt it can go to 70 volts and bottom that it can come to 50 volt.

If my range of operation if I can make between 15 to 71 volt or 69 volt I am still good with a 16 cells, 16 cells in series. If this voltage would have been a fixed voltage 3.65 no further changes it cannot go to 3.7 or it cannot come to 3.6 then there was a problem and if motor demands 60 volt pakka in it then there is a problem. Then I have to either get my cell design but no motor can also run between some voltage limits.

So, there is a question that why 16 cells we are taking why we are not taking 16 or 17 cells. So, the battery is designed to operate between some certain range. The minimum voltage for a cell can go up to 3.1 volt and the maximum range can go for 4.1 to 4.2 volt. So, the whole battery pack can go between 50 volt to 70 volt.

So, if I if someone requires or if my system requires a fixed voltage, so either I have to use a converter mostly DC DC converter to get a fixed voltage output or I can design the system other system also which can run between this voltage range. So, generally what we do we try to run the system between the voltage range major (())(12:08) is the major energy demand comes from the motor and it can by design operate between the voltage. However, when you are coming to the lower voltage your current requirement will go slightly higher when you are going to higher voltage your current requirement would be slightly lower.

So, now this is the engineering decision what I have to consider, so I will consider 16 cells. Because still it is still serve purpose to me. So, because of that now what we have considered 2P and 16S. Now, if I put so there are total 13 two numbers of cells. Now if I put all the cells in one line my battery pack will become very long may not be derive because I have a packaging constant my length cannot go beyond that. However, I have width available.

So, what we are doing now we are converting these 32 cells into two rows each row will have 2P8S. Now, it is easy if I put start putting the if I start putting cells in series two parallel always, I can go like this and my bus bar come like. So, current will flow like this and my output would be at the same place I do not have to put addition wire if might see if it would have been in single row.

So, all those things we have to decide before starting the battery pack design or during the design we have to think all the things. Now, the total numbers of cells in row is 16 in two row 32 the total weight of cell in cell total weight 32 cells together it is not one row it is complete battery pack is 10.24 kg. Now, what are the things I have to worry base plate end plates and side plate which should be able to take this load because much cell itself is weighing 10.24 kg.

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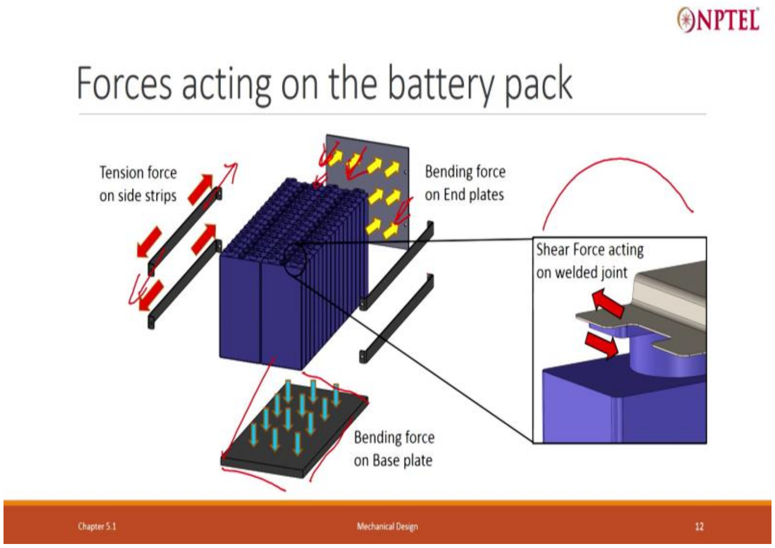

So, let us move to the next slide where we will see, what are the forces acting on the battery pack? The forces acting on the battery pack, what are the forces in the side strip, it is a tension because it is a trying to pull the plate end plate. So, it will get it is trying to pull this plate in this direction to create some pressure on the cell surface.

So, since it is trying to pull this surface the force acting on this side strip. Now side plate, end plate if you talk about end plate the end plate is constrained at the cell surface. The side trip is pulling it side strip is pulling here it is a pulling here. Cell is giving a reaction force in other direction what will happen. Now, in pulling this side and the some force is acting what will happen. It will start bending it will start bending like this.

So, that is why bending force on the end plate. Now, base plate all the weight is acting on that base plate and then this base plate is supported here here here and here at this book four plate is the base plate is supported. Same condition the reaction force comes at four edges now we are putting the load here same when bending will happen. So, these are the basic forces what I am talking about. It does not mean that other forces are not acting but this is the dominant force and that is why we are considering that one.

Now, the next slide. One more thing here the shear force the when the bus bar is welded on the cell terminals if there is any movement which is a continuous process when it is an operation in a vehicle, it will experience shear. So, the forces what I am talking in this slide what I am talking in this slide side strip, end plates, base plate, the bus bar these forces are dominant forces for that particular parts.

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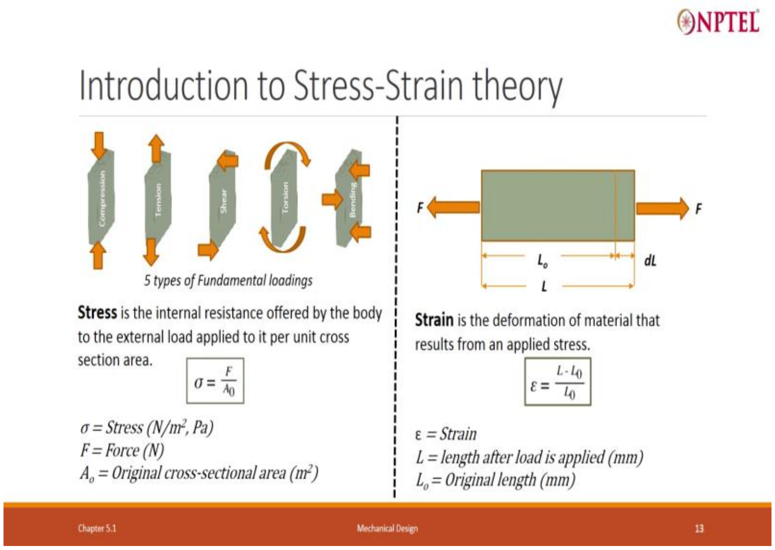

Now, you understood what are the type of forces acting on that one. Now, I am introducing a mechanical basic mechanical term is stress strain theory and the fundamental loads, there are five types of fundamental loads. Some of them we have already talked, but still I will take you back. This one is this the element and the force if force is acting like this then we say it is a compressive force or this phenomenon is known as compression.

If it is pulling outside, then it is tension if it acting perpendicular to the plane then it is shear it is all how do you define plane perpendicular and parallel it is all on that. So, I am defining this plane like this and if I am forcing like this way, if the force is going like this way this would be shear torsion if I am twisting like this that become torsion and the bending I am providing two force or multiple force from that and another hot applying force then it will bend if I am putting two force like this and one force at the centre it will bend like this.

So, that is comes as a bending. So, these are the anywhere these are the five fundamental loading or five fundamental forces acting on any element element is a smallest part from where we start doing all analysis. What is stress? Whenever you try to pull or compress a body resist to a certain extent and what we say that is the internal resistance in the terms of force, and how do we define? It is a force per unit area per unit cross sectional area. What is a unit of stress? Is a pascal similar to the flow and why we are saying original cross section area because if you further keep on pulling there would be some elongation and because of that elongation your cross-sectional area may slightly reduce. So, the original cross section cross-sectional area.

Now strain, because of action of the force there would be some increase or decrease in the length perpendicular to the your cross sectional area and the differential of that is known as the strength, that means if L is your original length sorry L0 is your original length and L is the length after the force is applied the strain is defined as L minus L0 By L0. Now, this would help this theory would help several other places. This a terminology known as elasticity or Young's modulus of elasticity that is a measured of how much it will extend or how much it will compress, how much the twist it can take, how much bending strength it takes.

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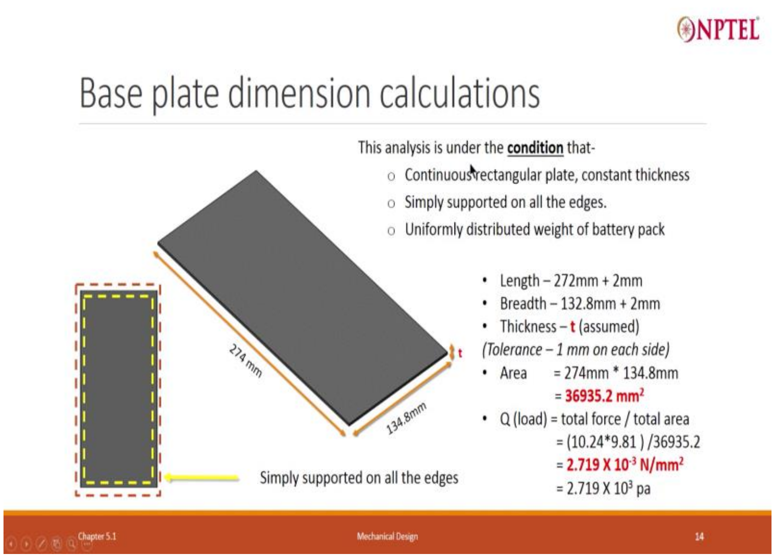

Let us, move to the next thing. Let us start designing the base plate, what base plate has to do base plate has to take the minimum the minimum requirement of the base plate is to take the cells load without failing without cracking without bending much. Because if is if it start bending then I cannot constrain much cells if I cannot constrain much cells my bus bar cannot be constrain if my bus bar is not going to constrain it would lead to a failure of bus bar.

So, now some assumption it is a continuous rectangular plate because much cells has stacked nicely as a rectangular plate of 274 mm 134 or approximately 135 mm. So, this we know already after the arranging the cell we already know that this is a dimension. What we do not know? We do not know the thickness of the plate required thickness of the plate.

So, let us calculate everything else. The load is 10.24 the load is 10.24 kg multiply with G that is the MG becomes weight divided by the total surface area available and that is comes 2.719 into 10 raise to the power minus 3 newton per mm square and that is if you multiply with a this is all newton per mm square is also equal to 1 mega pascal.

So, multiply with 10 to the power 6 that would become pascal. So, what we talk thickness then material. We have to select a material first then only we can talk about thickness. Now, we know the load, we know the area, we do not know the thickness and we do not know what the material.

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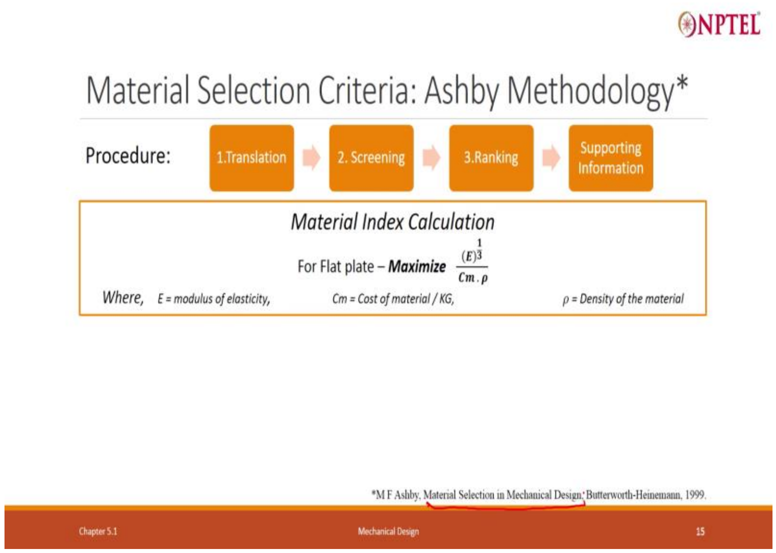

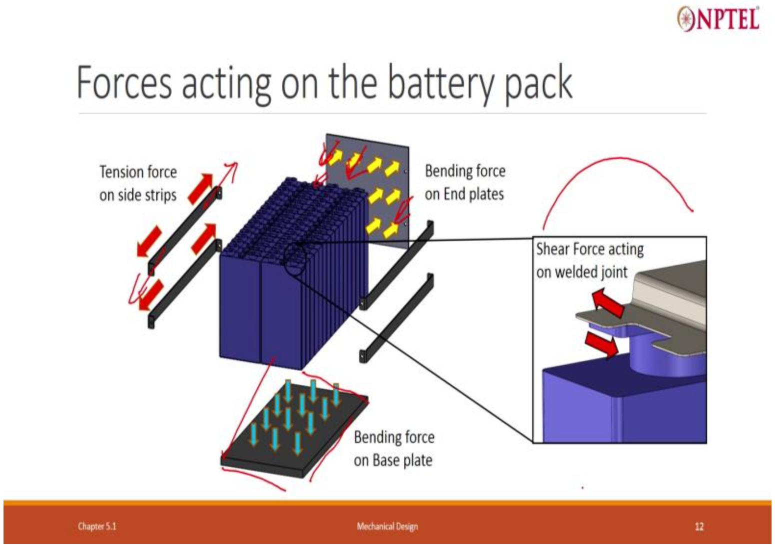

So, there is some nice methodology to select a material with all your objective function objective function means what you require, your strength is important, cost is important insulative properties important what is important or all those things are important. So, there is a nice methodology by Ashby it is known Ashby Methodology. There is a nice book you can see here material selection in mechanical design by him.

If you get a time go to that, however, I will explain the methodology here. How do we select a material has basically four stages first one is translation. Translation means you define your objective function. What is your objective? My objective here is maximum strength, minimum cost, minimum weight then you.

Student: insulation not insulation.

Professor: Insulation is my secondary objective, I can bring that as a primary objective. But right now these three are my. So, there is a question insulation is not is my primary objective or not. No, I put it as a secondary objective. However, if required I can bring that into primary objective, I will show you how.

Screening once you have your objective function. So, what you want to do, either you want to maximize that or minimize that based upon your requirement. What I want to do? I want to maximize the strength so that my thickness should reduce, I want to minimize the cost. So, 1 by cost I need to maximize. If I have to minimize the cost, so 1 by cost need to be maximize. I want to reduce the weight that means density of the material.

1 by density of the material if I maximize my weight will reduce, correct. Because mass is directly proportional to the density, then you rank whatever material you have you put all those objective functions there maximize or minimize depending upon is a and then rank. If you are putting a maximum maximize function, then the highest the rank you should select. Now, if you have two materials of the same ranking what you should do, then your secondary objectives comes into the picture.

Like insulation, so what we do we index material known as material index calculation. Four base plate it is basically flat. So, four four for flat plate what we need to do, we need to maximize strength basically we need to minimize the thickness. So, the deflection if you have seen my earlier slide. Bending force what it does the base plate also bending force so it will there is a uniform loading. So, where would be the maximum deflection at the centre of the plate.