Functional and Conceptual Design
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Lecture No. 25
Logical Method - TRIZ

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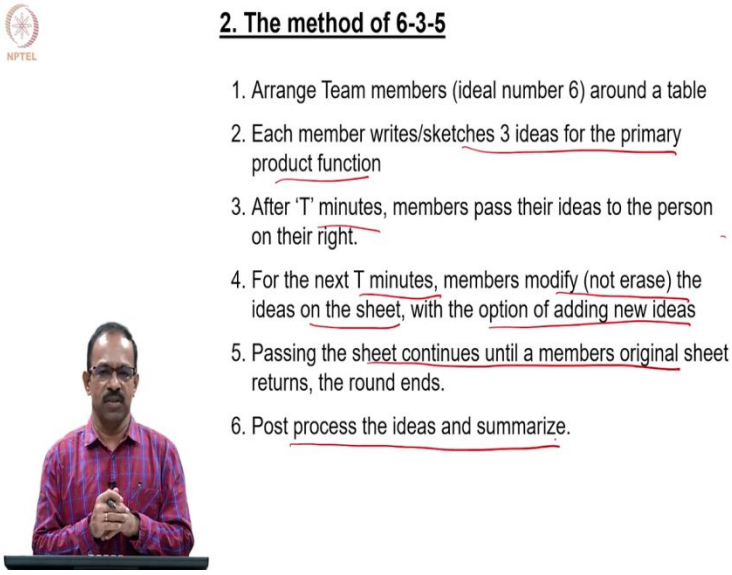

Hello, good morning everyone. So, we are discussing the various methods for idea generation as a first step towards the concept generation, we discussed one intuitive method yesterday and then briefly discussed the second method also. The first method was brainstorming, which is very commonly used in generating new ideas or to get a large number of ideas to solve a problem. And another method we discussed was 6-3-5. So, I briefly explained the method by which 6-3-5 is implemented.

We have 6 people sitting around a table and then each one will be given an A4 sheet for recording their ideas and they will be asked to write down 3 ideas, write down or sketch or whatever way they want, they want to express the idea. And they will be given a fixed time to do this stage. So, each member writes sketches, 3 ideas for the primary product function. And after T minutes, members pass their ideas to the person on their right. And for the next T minutes, members modify the ideas on the sheet with the option of adding new ideas and the passing the

sheet continues until a member's original sheet returns the round ends. So, that is the way how the first round goes.

At the end of the first round, the first person gets his own sheet back, and then he will see that the first 3 ideas whatever he suggested, that has gone a lot of modification and the new ideas have come in the sheet. So, at the end of this first round, each sheet will have 10 to 15 ideas to solve a problem and then after some discussion. So, there will be some discussion. And then the round continues.

They go for another 5 rounds. And finally, they process all the ideas, and then summarize the ideas. That is the way the 6-3-5 works. So, just to give you a brief idea of how each round will look like or how the people will start expressing their ideas in the sheet, we will take a very simple example and then see for some problems, how the ideas can be generated and how this can be explained in the sheet.

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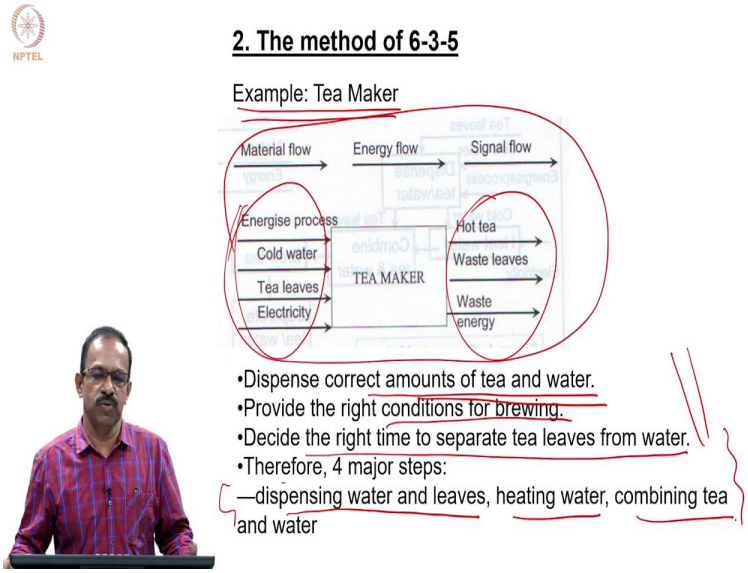

So, let us take the example of the tea maker. Again, in one of the earlier classes, I mentioned the functional decomposition of a tea maker, and then there we found different functions needed in the product. So, the product gets many functions, sub functions are there in the product. So, you can take one sub function and then see what kind of ideas can be developed for that particular

function, so, this actually shows the black box approach for the decomposition and these are the inputs these are the outputs. So, cold water, tea leaves, electricity or tea waste leaves, waste energy.

If you take this as the input and output and then you will be able to see that there are different requirements in the product, dispensed correct amounts of tea and water that can be a function needed. You need to have one function which will dispense water, one function maybe dispense tea. This needs to be in a proper proportion. We need to dispense correct amounts of tea and water. For these two functions, how can we actually get a concept for doing that or provide the right conditions for brewing to decide the right time to separate tea leaves from water. So, there are different requirements.

We can say dispensing water and leaves is a function, heating water is a function, combining tea and water is another function needed in the product. So, these are the functions that can be identified in the tea maker. Of course, there are many other functions needed, but then we are just trying to take out these functions and then see how we can develop concepts using 6-3-5 method.

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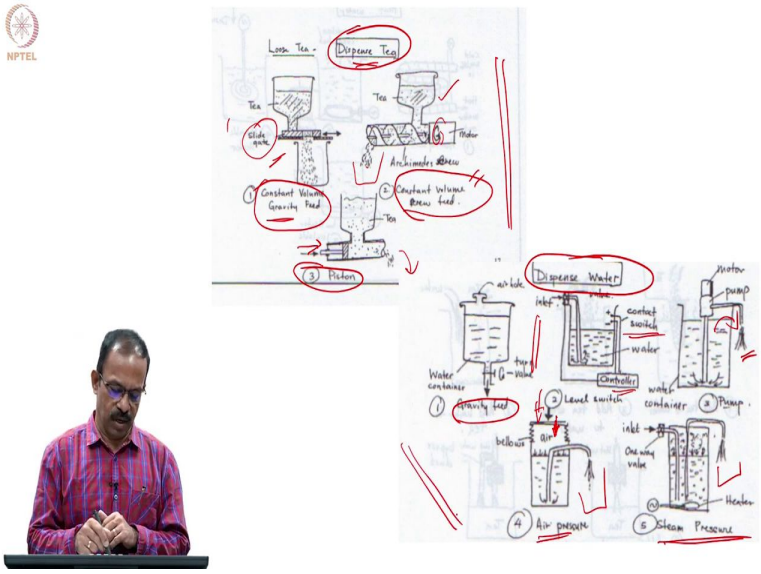

Look at this dispense of tea. So, you want to dispense a fixed amount of tea, tea leaves to make the tea. Depending on the number of tea required, you need to have a fixed amount of tea leaves to be dispensed. What are the ideas that we can have in order to do this? If you give this to a person in the 6-3-5 method, and ask him to sketch the ideas, then he can actually come up with many ideas like this.

One is this constant volume gravity feed. That is the name that he wants to give for this. So he is actually explaining that there will be a tea hopper in which the tea will be stored. And then you can have something kind of a slide gauge, so each time you slide it once and you will be getting a fixed amount of tea.

That speed at which you want to slide and what the stroke length is can be decided and based on that you will see a fixed amount of tea falling into that container. That is one method to get the tea dispensed for a fixed amount. Another method could be a constant volume screw feed. So, now assume that there is a, this is a tea hopper, storing the tea leaves and you have a kind of a screw feed and a motor and a screw. And then depending on the number of rotations that you make using the motor, you will get a fixed amount of tea leaves coming out here. That can be another idea to solve this problem.

If you make 2 or 3, depending on the number of rotations the motor makes, you will get the amount of tea so you can actually control it also. So, this is actually an idea, this is also a possibility and which one you want to choose depends on so many other factors.

Compared to the brainstorming method you will try to explain, you can use a screw feed or you can use a gravity feed but here it is much more clearer, what do you actually mean by gravity feed or what I actually mean by the screw feed is explained using a sketch and another method, it can be a piston method, you can have a piston cylinder piston kind of arrangement, and then one stroke of the piston use a particular quantity of tea leaves. So, that is the other method, it is a kind of gravity feed but in this case, it is not only the gravity you are actually using a push stroke of the piston to get it out, so that is the third method suggested.

This is the way the 6-3-5 will proceed and then you pass this to the next person. He will look at this and he will get some idea; “okay, oh you have this piston method gravity and screw feed. I can also think of some other method” and then, he will also come up with some methods to add. The ideas keep on adding in the paper. So, that is the way how it will proceed.

And another example and another function, suppose it dispenses water. So, dispense tea is a function and dispense water is a function; again you want to dispense a fixed quantity of water for making tea. So, what are the ways in which you can do so, you can actually do a gravity feed, as you can see here, something similar to this gravity feed but water dispensing. So, here we have gravity feed and a water container and a valve.

You can actually control the valve and then get the, it is a very common way of doing it. Another method is like this you can have a controller, an inlet valve, inlet and a valve, a controller, a controller will look at the water level and then based on the control input, it will just pump the water out. So, you will be getting the water out from the container using an electronic control that is the one idea. Here it is again using a pump, so you can just use a motor and a pump in a very conventional way. So, you use the pump to get the water out of the container.

You can turn the pump for a particular duration and you will get the water coming out. Another one is an air pressure type. So, you can actually have air pressure, so this is below. So, you actually apply some force here to move the bellow. Then you will be getting the pressure air will be pressurized and that will actually pump the water out so that is another method.

And another one is the steam pressure, instead of having a manual pressure application you can apply a steam and that will actually pressurize the water inside and then the water will come out. That is another way of looking at it. So, if each one is suitable, which one is feasible, we do not worry about whether that is highly difficult or very easy, how much complexity it will bring, all those things are not considered here, you write whatever idea you feel is good. So, whatever you think can be used, please keep adding it. So, you will get a lot of ideas like this.

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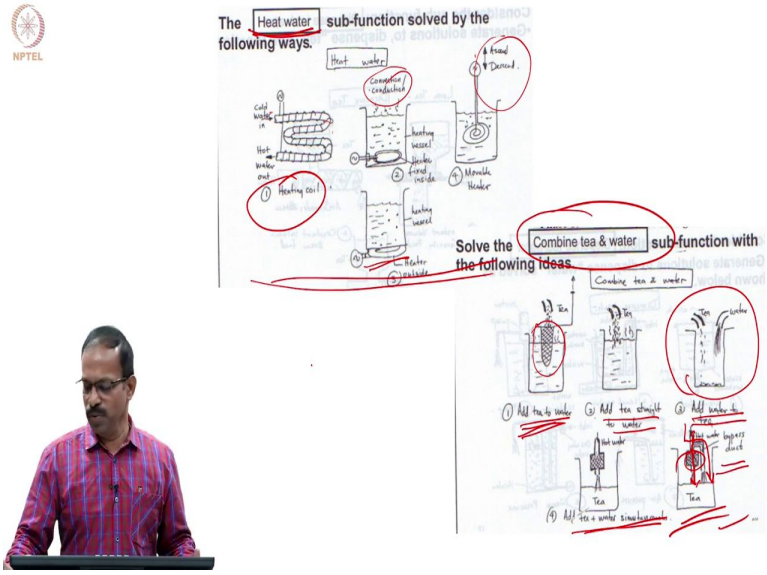

Another function here heating water, suppose, you want to heat water is a function. So, you can actually have brainstorming or a 6-3-5 method, idea generation session for individual functions. Each function you can take and then do an idea generation session and then you can get ideas. So, heating water so you can use a heating coil.

Water will pass through the pipe and then you can have a heat coil round over it then you will get and heating this you will get hot water. Another one is the conventional conduction mechanism, you have the heating coil at the bottom of the container and then you will be using that to heat the water. The third one is an immersive coil. So, you can actually immerse the heating coil into the water and then heat it or you can have a heater outside the container.

You can keep it outside the container and the heat will be used to heat the whole container and the water will get heated. I mean then you can heat the water. So, these are the ideas of course, you can have many more ideas like this. So, you start with some ideas and then keep moving the paper to the next person and then keep on adding ideas. So, another function is to combine tea and water.

You can combine this, you need to have a fixed amount of tea and a fixed amount of water and the water is heated now you need to mix this tea and water. So, how do we do this? We can

actually have different ways of doing this. One is to add tea to the water. So, you have the water boiling a fixed amount of water and then boiling and then you add the tea powder directly like this or you can have tea straight to water.

Instead of using a sieve like this you can insert, I mean directly add or you can add water and tea together. We can have a fixed amount of water coming from the water dispenser, a hot water dispenser and then a fixed amount of tea coming from the tea dispenser. Both can be added into a container you will get that also is a way of mixing or you can have water passing through the water and hot water coming and through a tea container or a tea sieve and you get the tea here.

Here it is hot water bypass the deck so you can help one valve pass through the hot water like this one small m quantity of water passing through the tea sieve, then you will get the answer. So, here you can actually control the amount of water passing through this you will be getting a can have better control on the quality of the tea. So, these are the ways in which you can think of getting the, this combining tea and water.

This is how we actually do the 6-3-5 method of idea generation. So, the advantage here is that you can have much better clarity on what is the idea that you are proposing, you can sketch it, you can explain it the way you would like to explain and write down all the details. So, the person who is seeing it will get a better idea and better understanding of what we are proposing and you will be able to take it forward. That is the 6-3-5 method.

The first one was brainstorming where you, it is more vocal than graphical or creating sketches. Here it is more of creating sketches and then limited interactions. So, these are the two methods. Now, this also has some limitations because you do not have, you cannot really explain the idea to the other person, he may understand it based on the sketches and whatever you mentioned, probably you do not have that you do not have enough opportunity to explain this to the other person. That is one limitation here compared to the brainstorming.

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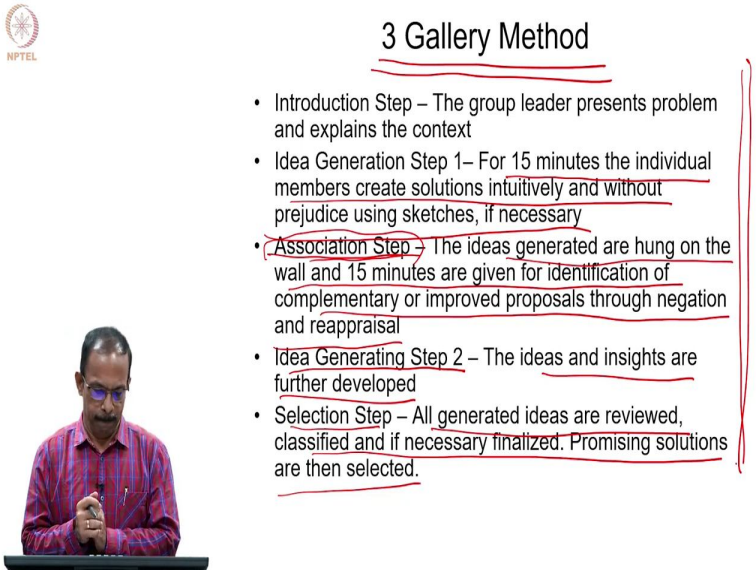

To avoid this issue, people have come up with a slightly different method, which we call it as the gallery methods. So, the gallery method is a kind of combination of both brainstorming and 6-3-5. Here what we do is, we will ask every individual to sketch his ideas and present it to the group. So, in this idea generation step for 15 minutes, the individual members create solutions individually and without prejudice using sketches if necessary.

Asking them to sit around that table. Each one will be given a big sheet kind of a poster sheet, and ask them to sketch their ideas and explain it the same way what we do in the 6-3-5 method in the first stage, so everyone will be given 15 minutes to sketch their ideas and whatever they want to write down and they explain, all those things can be done in the on the sheet, and then what they do this step this one as the Association step, the ideas generated are hung on the wall and 15 minutes are given for identification of complementary and improved proposals through negation and reappraise it.

What will happen, all the team members will be preparing the sketches and they will hang it on the wall and then they will go to each other and then discuss what the idea that they mentioned is and what are the pros and cons and what are the things they want to explain. So, they will

explain, this is my idea, this is how it works, and the other person can actually tell, this can actually be modified there can be a different way of doing it.

That way they will be able to improve the ideas in the association step. So, this is to some extent a combination of the 6-3-5 and the brainstorming. So, for some time there will be some brainstorming happening after that initial step of idea generation. And this association step will help everyone to improve their ideas based on the feedback they receive from the individuals. And again, they will go back and then redo the ideas and get more ideas.

That is the ideas generation step two, the ideas and insights are further developed based on the association step and this will continue for 2 or 3 rounds, and then they will stop and then they sit together and consolidate all those ideas generated and then see how to take it forward. So, that is known as the gallery method. The selection step, all generated ideas are reviewed, classified and if necessary, finalized promising solutions are then selected.

Based on the first level of idea generation, they will sit together and work, look at all the ideas generated and then see what are the promising solutions and then decide to take it forward. So, that is basically known as the gallery method of idea generation. So, these are the 3 intuitive methods. So, the first method is brainstorming methods, the second one is 6-3-5 and the third one is the gallery method.

You can use any one or all these methods to generate ideas. So, the more ideas the better the final solution that is the basic premise. So, you can have any number of ideas generation sessions and any number of times you would like to do it and any method you can adopt and try to see how you can actually improve the total number of ideas generated for a particular problem. So, that is the first stage in the concept generation or concept development.

Now, you need to take it forward to the next level of finding out the concepts. As I mentioned , the ideas need to be converted to more concrete concepts. So, that is the stage where everyone will work together and then convert these ideas into concepts. The concepts will be a more concrete way of representing the solution that you can use for solving the problem. So, these are the three intuitive methods we discussed.

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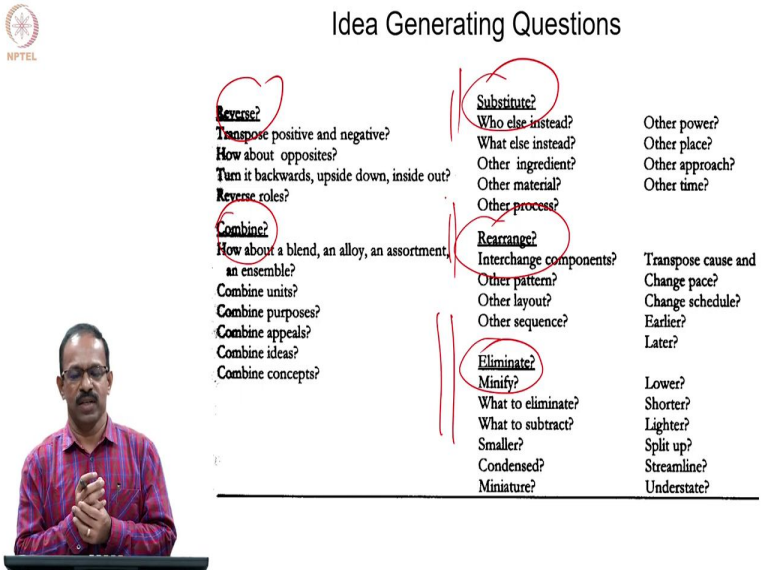

And as I mentioned during any of these idea generation sessions, you need to ask some questions to ensure that the idea keeps flowing. And so, these are some of the tips that you can use, put to other users. So, how to have other applications, a particular problem or solution, new ways to use other users if modified, other places to use and other people to reach.

These are the questions that you can ask, can we use it in some other ways? Or is there any other method which actually uses the same principle? Are there any other areas where this principle is being used? Are there other people who are using this to solve a problem? So, these kinds of questions are the one which the leader should ask the team so that they can actually keep the momentum similarly adapted? How to adapt something existing?

Is there any way to adapt the existing technical methods and modify the existing methods? Can we give a new twist to this? Or can we change the meaning color, motion, odor, taste, form or shape to suit a particular requirement and magnify? Can we expand things, can we add something, can we increase the time of application or can we have more frequency of using this. So, these kinds of questions in the magnify category and then minify the basically the other side you can, can you reduce something, can you reduce the time, can you reduce the frequency? Can

you miniaturize, can you lower the temperature or can you lower the weight? So, these are the kinds of questions you can ask.

So, let me reverse combine something, substitute something rearrange, eliminate. So, these are the key questions the team leader should ask or the team members also can actually keep asking these kinds of questions to themselves so that they will be able to come up with new ideas. The reason why we are asking these questions is to keep the thinking in different directions.

We want the participants to think differently in different directions. That is why we keep asking these questions that will actually trigger the ideas and then that may lead to more good ideas coming out. So, the leader should have the ability to ask questions and then trigger the participants to come up with new ideas. That is the importance in the intuitive method of idea generation.

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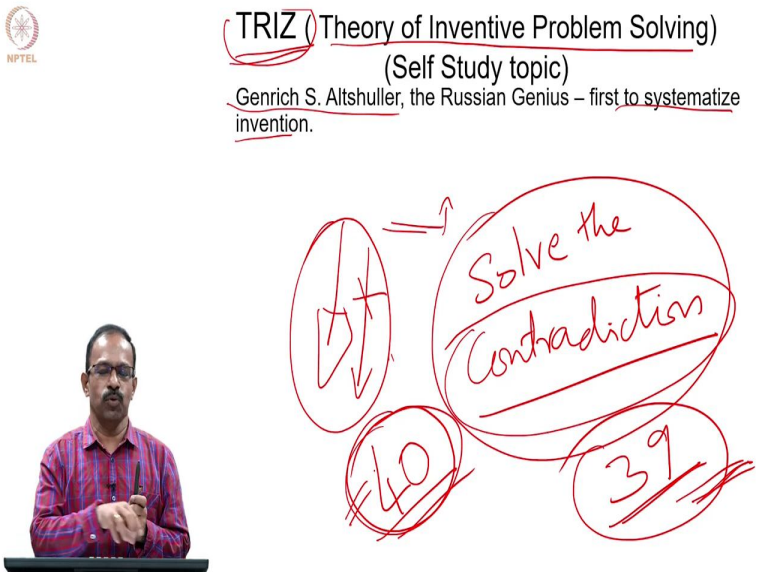

Let us discuss the logical method here. So, the last 3 methods that we discussed, they are the intuitive method, where the intuition of the participants plays a major role in getting a solution but in the logical method, we have a logic incoming with a solution, it is not based on the intuition, but it is based on some logic. So, if there is a problem, then this could be the solution because of so and so reasons that is basically a logical based idea generation.

This was proposed by a Russian genius, his name is Genrich S.Altshuller he was the one who actually systematized the invention, he said the invention can be named in a systematic way. So, that was his proposal, if you want to invent something, there is a way to do this. So, you go in, take those steps, then you will be able to invent, make inventions. So, that is the proposal he made.

And this was known as theory of inventive problem solving, or TIPS in English. So, we call it TIPS. So, TRIZ was the Russian acronym. So, he was a Russian scientist, he coined this terminology in Russian language and the English conversion his theory of inventive problem solving, so, how can we solve problems using inventive methods and what is the theory for that, so he proposed the theory of problem solving.

Finally, he said that any invention can be done in a systematic way. So, normally we think that invention is not a systematic process, you keep on searching and you will find a solution, but he says no, no, do not do it that way. There is a systematic way of approaching the problem and you can solve it. That is the theory of inventive problem solving. So, in the conventional way, suppose you want to solve a problem, and you do not know where the solution lies, you keep on searching for the solution.

Suppose, this is the timeline and this is the space where actually you need to search for solutions. And you are the problem, a solution maybe somewhere here it may be lying somewhere here. So, you keep up searching all these places and then you keep on searching. And finally, you reach here. And then you will be able to get the solution. Probably it will take maybe 2 years or 3years to reach the solution, because these two are actually the solution.

You don't know the solution where it is you keep on searching all the space and then you find it. But also Altshuller said, you do not need to do this, you tell me what is your problem, I will tell you where will be the solution space or what will be the solution space, you go there and search only you do not need to search our space to get the solution, you go to that particular location where the solution can be found.

And then you search for the solution you will find for example, now he is saying, suppose this is the way normally we do the invention. He says that you tell me the problem, I will tell you, if this is the problem, your solution will be lying somewhere here. So, this is the only place where you can find the solution so that you can actually jump directly and then search for it. You will be able to get the solution in a much shorter period of time.

This is the proposal he made. That is the essence of the TIPS methodology or is that you if you have a problem, I convert that problem into a systematic or a standard problem, your problem will be converted to into a standard or a generalized problem and then I will tell you where you can actually find solution you go there and find a solution. So, that is what actually he proposed and how did he come up with this solution or this methodology? Basically, he looked at the patents available all over the world.

This person looked at patents so all of you know that a patent is a document that you can see, when you do an invention, you file a patent application and then the patent authority will give you a patent saying that you are done with this invention, and these are the details of the invention. You have the right to use it. That is a patent in general. And all this patent information will be available in the public domain so that you can search for the details.

So, whenever you have a you want to or when you want to know something about you can actually search for the patent and you will see people have tried to solve it in different ways and each one how they solve the problem. Now, this person actually looked at all around 400,000 patents, he searched all the patents available in the world, because these are publicly available data. So, he sets all the patents and then each patent he tries to analyze what the inventor is trying to do. So, he was trying to solve a problem.

And then he found that every design problem he had they were trying to address kind of a design contradictions. So, all the patents because you want to improve something you want to improve something, for example, you want to reduce the weight of something, you want to reduce I mean, you want to reduce the weight of something that is your requirement, but when you try to reduce the weight, what will happen, the strength will also come down.

The strength also will come down, which you do not like, you do not want the strength to come down, you want the strength to remain the same, or you want the strength to go up. But this is a contradiction. So, it is not possible to reduce the weight and then have the same strength. So, that is a contradiction in the design. Now, somebody will try to come up with a method to solve it, then he will get a patent and he will say, this is the method by which I tried to reduce the weight and then still maintain the strength. Like this, he tried to study all the patents, and he found that every patent is basically a solution to a contradiction.

That was his first understanding. So it is a contradiction in the design space. So, everyone is trying to solve a contradiction existing. Guess all the contradictions that are the first thing he understood. So, there is a contradiction in all the patents whatever patent he has tried to understand, he found that there is a contradiction between two parameters in the design. So, for example, like strength and weight, that is the way or the pressure to apply it and the force to be used things like that.

And he found that all these contradictions can actually be and looking at all these contradictions, he found that there are only very few parameters which are contradicted or all those 400,000 patents he tried to understand, he found that the contradiction can be generalized into few parameters only. And he realized that there are only 39 engineering parameters that contradicts any design you take or all the designs that are existing in the current world or the current patents are available.

He found that there are only 39 engineering parameters that can contradict or any design problem can be considered as a contradiction between only 39 engineering parameters that was the first realization he had. And then again he tried to understand, if there is a contradiction between one parameter and another parameter, what is the way they try to solve it? And then he realized that there are only 40 engineering principles that can be used to solve all the contradictions existing in the world.

That is all those patents, what are the 400,000 patents available, they used only 40 principles to solve a problem, all the principles they use to solve the contradictions can be brought down to 40 engineering principles. And then using this he said, Now, you tell me your design problem, I will

tell what are the contradictions existing in that design problem, and I can tell you if this these are the contradictions, then I can tell you which principle can be used out of these 40 which principle can be used for solving the problem,.

So, that is the TIPS methodology theory of inventive problem solving. So, it says that, if you have a design problem or any problem you are trying to solve, I can convert that into a contradiction problem between two parameters to engineering parameters. So, initially you may not look like you, you may not see that as a parameter, but based on the TIPS, terminology, I can find out the contradict parameters. And if I know the contradicting parameters, I can tell you which principle to use for solving it so that you do not need to search anywhere else. You can only solve this problem through this principle only. And if you are not able to solve this, through this principle, there is a very high chance that you will not be able to solve it.

That it was the principle of that was the TRIZ methodology proposed by Altshuller. So, let us briefly go through the process of TRIZ and see what the parameters are, and what the design principles that can be used are. So, this I am leaving it as a self study topic for the time being, but I just briefly tell you, but you need to go through, read about it, and then there are a lot of literature available, you need to do some kind of self-study to understand it in a much better way.

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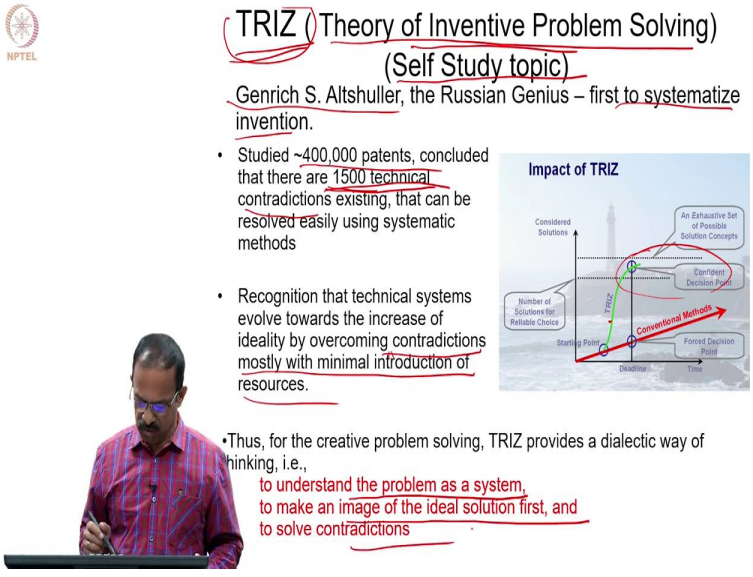

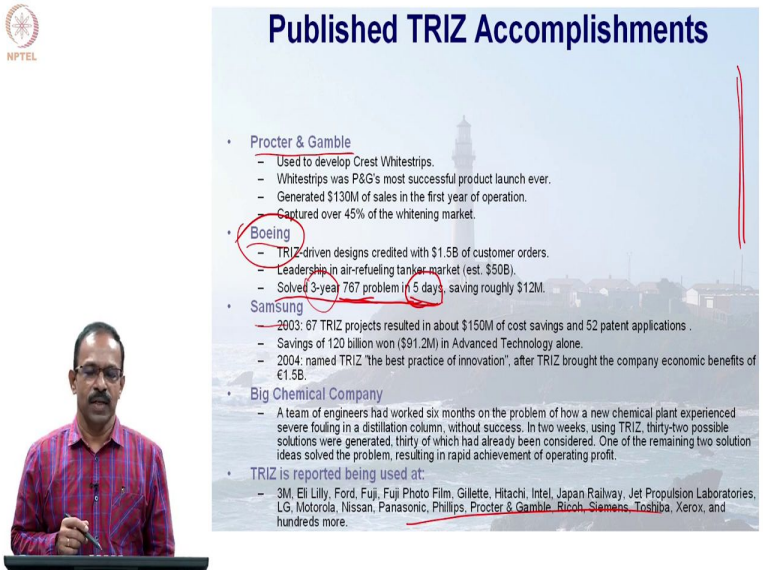

This one I already told you the TRIZ will take you to the solution space very fast okay. And he studied around 400,000 patents. So, he found that there are only 1500 contradictions existing. So, there is a contradiction and these contradictions can be converted to parameters. So, there can be only 39 parameters that will contradict but total contradiction can be 1500. And then, then you Find the parameter out of these 1500, what kind of parameters are involved and find that there are only 39 parameters involved. And the recognition of the technical system evolved towards the increase of ideology by overcoming contradictions mostly with minimal introduction of resources that is the recognition heard.

Very minimal resources can be used to overcome the contradictions, okay. So, the methodology is to understand the problem as a system, make an image of the ideal solution first and then solve contradictions. So, you solve the contradiction by idealizing using the parameters and then solve the contradictions and this is not just a theory. So, there are a lot of industries using this methodology, TRIZ methodology to solve their problem.

If you take any major companies like Procter and Gamble, Boeing, Samsung, etc, there are so many other companies which actually use the TRIZ methodology to solve the problem, one of the very interesting one is the Boeing case study. So, they had a very big design problem In the Boeing 767. So, they were trying to solve a design problem in Boeing 767 and they actually

spent 2, 3 years trying to solve it, and they could not really reach the solution space. And when this by that time when the TRIZ was introduced, they tried to apply this TRIZ principles, and this 3 year problem they could actually solve in 5 days.

That is actually a case study from Boeing saying that they could actually solve the problem, which was already they were working on it for 3 years. But then when they applied the TRIZ methodology, they could actually solve it in 5 days. The reason is that they were actually searching all over the place for the solution. But TRIZ said, if this is the problem, you can actually find a solution only in this particular space.

You go to that space and then search for the solution, you will find it. So, that is why they could actually solve the problem and they actually saved around 12 million dollar in by solving this problem using TRIZ methodology.

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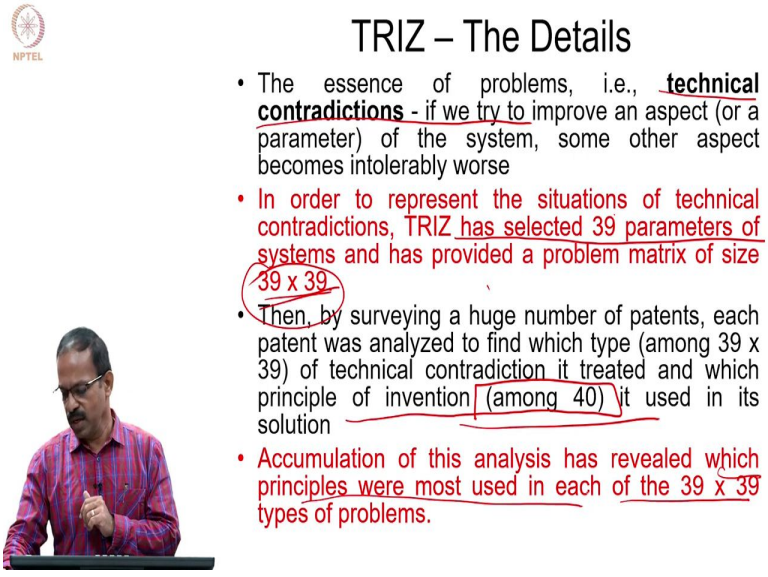

What is TRIZ, let me go to the details. So, the essence of the problem, technical contradictions. So, TRIZ says that the technical contradiction is the most important thing that needs to be understood in any design problem. What is the contradiction that you have and then they identify that there are only 39 parameters of systems and have provided a matrix of 39 by 39.

He said or he identified there are only 39 parameters, now, you can actually create a matrix of the 39 parameters, that is, you have a parameter. So, you want to improve this parameter. So, for example, you want to improve the strength of something and then you see that this is something which actually goes against your wishes.

So, the weight of the object is going against it that means, you have a contradiction between the strength and all these 39 parameters, they have this contradiction, I mean, it can have find out the contradiction between parameters not necessarily that every parameter will be having a contradiction with each other, but there can be parameters which contradict when you try to improve this. Suppose, this is the improving parameter, and this is the one which is actually going against that parameter.

Now, this is the 39 by 39 matrix. Now, we want to know if there is a contradiction between strength and the weight and I am trying to improve the strength and the weight is actually going against my requirement. What kind of solution can be used to solve this? So, that is what we need to know now, then we can actually have that kind of solution identified and then we will be able to get the solution space very easily. So, that is the 39 by 39 matrix that we can have between the contradiction parameters, contradicting parameters.

Now, by surveying a huge number of patents, he found that there are only 39 by 39 and there the principle of in which principle of invention to be used and he found that there are only 40 principles available that can be used for solving the contradictions, any contradiction, you will be able to solve by any of these 40 principles not all 40 need to be used, but there may be three or four principles that can be used to solve the problem.

That is the 40 design principles. Now, out of these 40 there may be only 4 or 5 which are very commonly used to solve the contradiction. So, you list those principles into that matrix. So, whenever we have that 39 by 39 matrix between the two parameters, the contradiction is existing, you identify the principles which can be used to solve it and then you prepare a 40 by 40 design contradiction matrix with the design principles that becomes the basis for the all the problem solving using TIPS.

You have the 39 parameters, 40 principles and a contradiction matrix explaining what principle to be used to solve a contradiction. So, that is the TRIZ, okay accumulation of this analysis revealed that in each of the 39 by 39 types of problems, so which principles are most used in each of the 39 by 39 parameters, so, he identified all those parameters as those principles and then listed it in the matrix saying that if you have a contradiction between this parameter and this parameter, use the principle 6, 8 or 10 like that he listed and now whenever you have a design problem, you can just identify the parameters and then see which principle can be used and then start using that principle to solve the problem.

It does not give you a direct solution. It will tell you what kind of design principles can be used to solve and then you search for it and then get the solution that is the TRIZ methodology.

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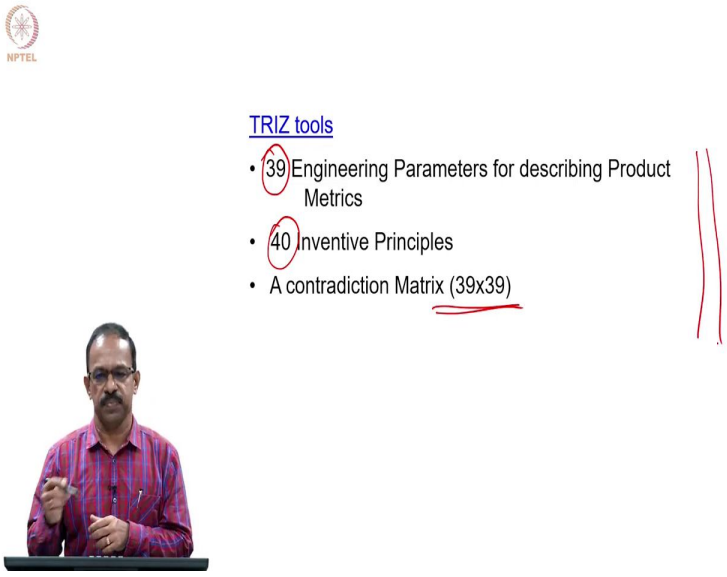

So, 39 engineering parameters, 40 inventive principles and a contradiction matrix of 39 by 39. So, this is the TRIZ methodology. I hope you understood this.

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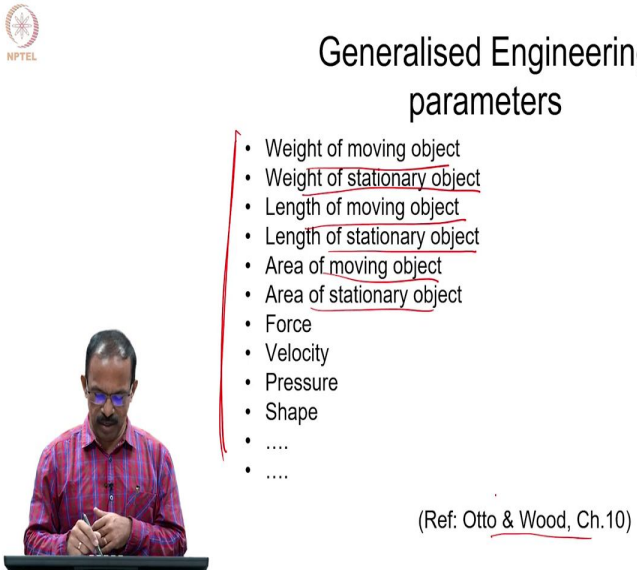

So, these are the parameters that are identified by the inventor or Altshuller. So, weight of moving object, weight of stationary object, length of moving object, length of stationary object, area of moving. So, like this he had identified 39 parameters; force, velocity, pressure etc. You can refer to the textbook you will receive the complete listing of the parameters.

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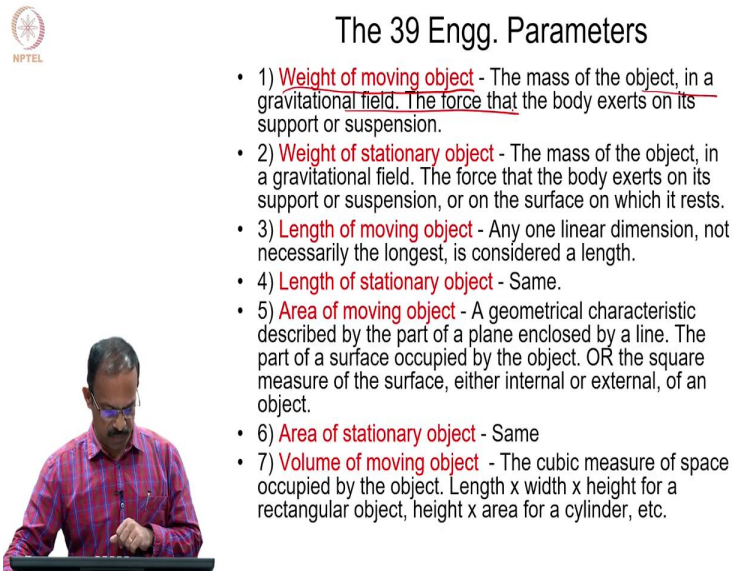

- 8) Volume of stationary object - Same
- 9) Speed - The velocity of an object; the rate of a process or action in time.
- 10) Force - Force measures the interaction between systems. In Newtonian physics, force = mass X acceleration. In TRIZ, force is any interaction that is intended to change an object's condition.
- 11) Stress or pressure - Force per unit area. Also, tension.
- 12) Shape - The external contours, appearance of a system.
- 13) Stability of the object's composition - The wholeness or integrity of the system; the relationship of the system's constituent elements. Wear, chemical decomposition, and disassembly are all decreases in stability. Increasing entropy is decreasing stability.
- 14) Strength - The extent to which the object is able to resist changing in response to force. Resistance to breaking .
- 15) Duration of action by a moving object. The time that the object can perform the action. Service life. Mean time between failure is a measure of the duration of action. Also, durability.

- 16) Duration of action by a stationary object - Same.
- 17) Temperature - The thermal condition of the object or system. Loosely includes other thermal parameters, such as heat capacity, that affect the rate of change of temperature.
- 18) Illumination intensity - Light flux per unit area, also any other illumination characteristics of the system such as brightness, light quality, etc..
- 19) Use of energy by moving object - The measure of the object's capacity for doing work. In classical mechanics, Energy is the product of force times distance. This includes the use of energy provided by the super-system (such as electrical energy or heat.) Energy required to do a particular job.
- 20) Use of energy by stationary object - same
- 21) Power - The time rate at which work is performed. The rate of use of energy.
- 22) Loss of Energy - Use of energy that does not contribute to the job being done. See 19. Reducing the loss of energy sometimes requires different techniques from improving the use of energy, which is why this is a separate category.

- 23) Loss of substance - Partial or complete, permanent or temporary, loss of some of a system's materials, substances, parts, or subsystems.
- 24) Loss of Information - Partial or complete, permanent or temporary, loss of data or access to data in or by a system. Frequently includes sensory data such as aroma, texture, etc.
- 25) Loss of Time - Time is the duration of an activity. Improving the loss of time means reducing the time taken for the activity. "Cycle time reduction" is a common term.
- 26) Quantity of substance/the matter - The number or amount of a system's materials, substances, parts or subsystems which might be changed fully or partially, permanently or temporarily.
- 27) Reliability - A system's ability to perform its intended functions in predictable ways and conditions.
- 28) Measurement accuracy - The closeness of the measured value to the actual value of a property of a system. Reducing the error in a measurement increases the accuracy of the measurement.
- 29)Manufacturing precision - The extent to which the actual characteristics of the system or object match the specified or required characteristics.

- 30) External harm affects the object - Susceptibility of a system to externally generated (harmful) effects.
- 31) Object-generated harmful factors. A harmful effect is one that reduces the efficiency or quality of the functioning of the object or system. These harmful effects are generated by the object or system, as part of its operation.
- 32) Ease of manufacture - The degree of facility, comfort or effortlessness in manufacturing or fabricating the object/system.
- 33) Ease of operation Simplicity: The process is NOT easy if it requires a large number of people, large number of steps in the operation, needs special tools, etc. "Hard" processes have low yield and "easy" process have high yield; they are easy to do right.
- 34) Ease of repair - Quality characteristics such as convenience, comfort, simplicity, and time to repair faults, failures, or defects in a system.
- 35) Adaptability or versatility - The extent to which a system/object positively responds to external changes. Also, a system that can be used in multiple ways for under a variety of circumstances

36) Device complexity - The number and diversity of elements and element interrelationships within a system. The user may be an element of the system that increases the complexity. The difficulty of mastering the system is a measure of its complexity.

37) Difficulty of detecting and measuring - Measuring or monitoring systems that are complex, costly, require much time and labor to set up and use, or that have complex relationships between components or components that interfere with each other all demonstrate "difficulty of detecting and measuring." Increasing cost of measuring to a saticfactory error is also a sign of increased difficulty of measuring.

38) Extent of automation - The extent to which a system or object performs its functions without human interface. The lowest level of automation is the use of a manually operated tool. For intermediatel levels, humans program the tool, observe its operation, and interrupt or re-program as needed. For the highest level, the machine senses the operation needed, programs itself, and monitors its own operations.

39) Productivity - The number of functions or operations performed by a system per unit time. The time for a unit function o operation. The output per unit time, or the cost per unit output

Some explanation is given for all this, the weight of moving objects is the mass of the object in a gravitational field. And weight of stationary objects. So, we can see what is that parameter representing what actually the parameter represents, can be seen in the textbook. So, I am not going into the details of it, please read it and understand Okay, these are the 39 parameters.

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'40 Inventive Principles'

- 40 principles are listed starting with division and including taking-out, asymmetry, universality, dynamization, composite materials, etc..
- Most of the principles have a few sub-principles and all are illustrated with a number of actual cases for reference
- They are expressed in a way independent of specific fields of technology

40 inventive principles

Principle no.	Principle title	Principle no.	Principle title
1	Segmentation (Fragmentation)	21	Rushing through(Skipping)
2	Extraction(Taking out)	22	Convert harm into benefit(Blessing in Disguise)
3	Local quality	23	Feedback
4	Asymmetry (Symmetry change)	24	Mediator(Intermediary)
5	Consolidation(Combining)	25	Self service
6	Universality(Multi Functionality)	26	Copying
7	Nesting (Matrioshka)	27	Dispose
8	Counterweight(Anti-Weight)	28	Replacement of a mechanical system
9	Prior Counteraction	29	Pneumatic or Hydraulic construction
10	Prior Action(Do It In Advance)	30	Flexile films or thin membranes
11	Cushion in advance(Cushioning)	31	Porous materials
12	Equipotentiality	32	Changing the color(Color Changes)
13	Do it in reverse(The Other Way Around)	33	Homogeneity (Uniformity)
14	Spheroidality (Curvature)	34	Rejecting and regenerating parts
15	Dynamicity(Dynamics)	35	Transformation of properties
16	Partial or Excessive action	36	Phase Transition
17	Transition into a new dimension	37	Thermal Expansion (Relative Changes)
18	Vibration	38	Accelerated oxidation(Strong Oxidation)
19	Periodic action	39	Inert environment(Inert Atmosphere)
20	Continuity of useful actions	40	Composite materials

And then you have 40 inventive principles, the principles are listed starting with the division and taking out asymmetry, universality, dynamization, composite material etc. So, these 40 principles and again they are just the principle only. You need to find what way this principle can be used to get a solution. For example, you can see the principle of segmentation or extraction.

It says extraction, you take out something. If there is a design problem, see whether you can take out something and then solve the problem. To give an example, suppose you look at the air conditioners, we had this window air conditioners. So, this window air conditioner when you switch on, there will be too much noise coming from the air conditioner. It is actually a problem for people who want to sleep without any disturbance, the air conditioner noise should be always there in the room, when you switch on the AC.

Someone was trying to see how you can reduce the noise. That was a design problem you wanted to reduce the noise. One way to reduce the noise is basically to reduce the compressor or improve the compressor design, so that it will not generate noise that is one option. But then there can be another option like that, which is making noise to take out that part and separate it that is basically you take out, extract it; that is the way how we actually that problem was solved.

Actually the compressor which was actually creating noise, it was taken out from the windows side and then just kept separate that is why we got the split air conditioner. Now, the split air

conditioner the compressor is given separate and the air unit is separate. And therefore, you could actually solve the problem of the noise by taking out something which actually creates the user problem. So, that is the principle that we will say.

"Taking out" is a principle that can be used to solve a design problem, but what to be taken out, how to take out, what are the other implications that are to be decided by the design, it simply tells you a principle that can be employed to solve the problem. So, that is the way how this principle can be used to solve the design problems.

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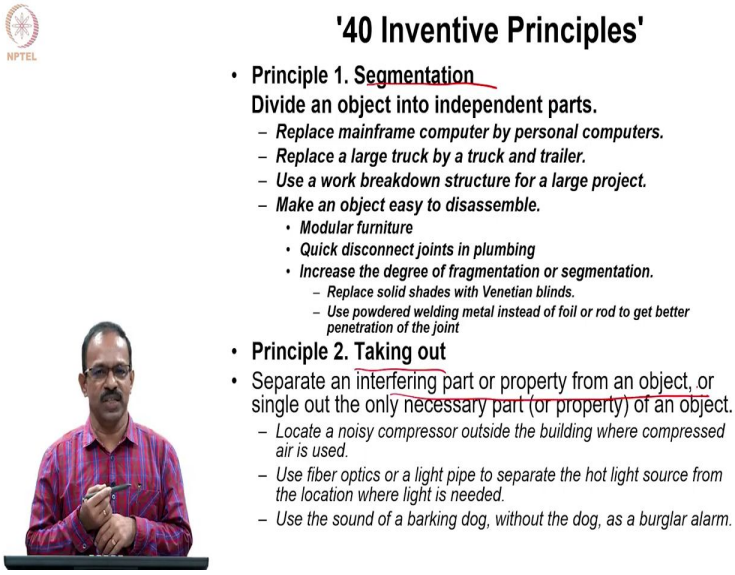

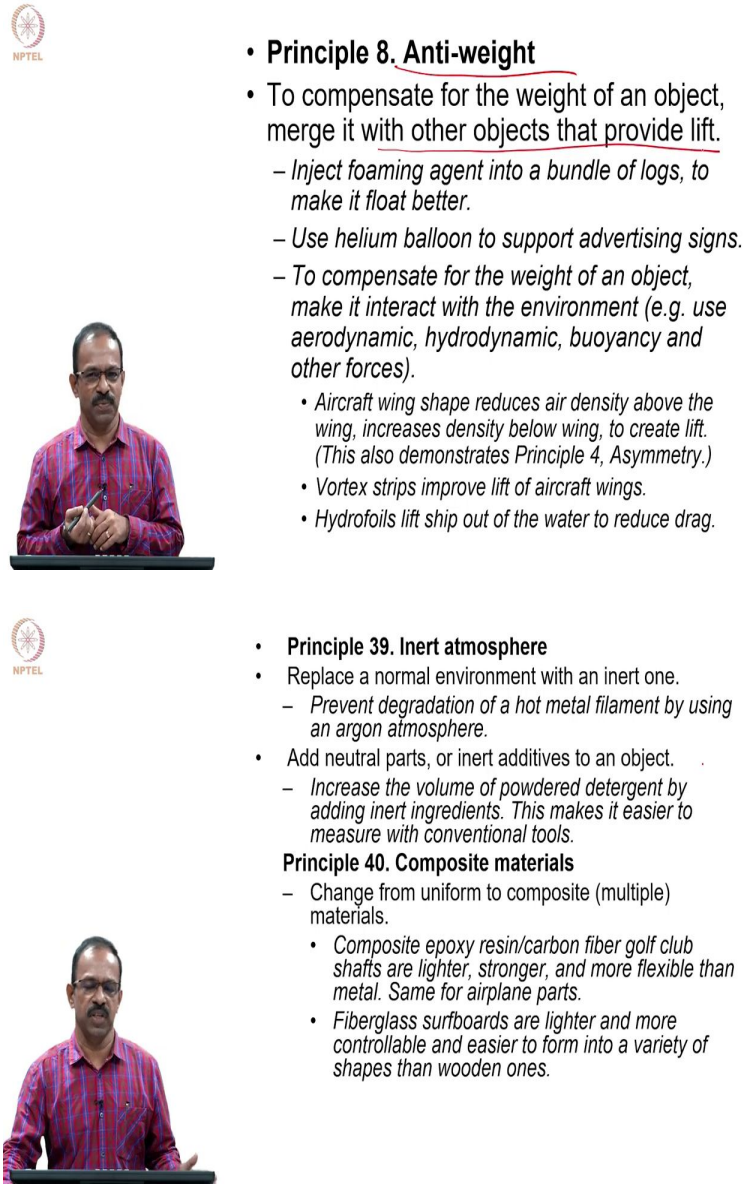

So, segmentation is divide an object into independent parts, taking out a separate interfering part or property from an object and anti weight is to compensate for the weight of an object merge it with other objects that provide lift and like that, you can actually see the all this principles, I am not going through that each principle. Again, you can refer to the standard textbooks or there is a lot of online literature available on TRIZ. So, you can actually refer to some of this literature.

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'Contradiction Matrix'

- 'Which Inventive Principles should we use for solving our specific problems?
- Altshuller built a large reference table named the 'Contradiction Matrix'
- Thus he set up a 39 x 39 table (or a matrix) with these parameters.
- The top four most frequently-used principles were shown in each box of the matrix

	Undesired result (Conflict) / Feature to Change	1 Weight of moving object	2 Weight of non-moving object	3 Length of moving object	4 Length of non-moving object	5 Area of moving object	6 Area of non-moving object	7 Volume of moving object	8 Volume of non-moving object	9 Speed	10 Force	11 Tension, pressure	12 Shape	13 Stability of object
1	Weight of moving object			15, 8, 29, 34		29, 17, 38, 34		29, 2, 40 28		2, 8, 15 38	8, 10, 18, 37	2, 36, 37, 18	10, 14, 35, 40	1, 35, 19, 39
2	Weight of non-moving object				10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2		8, 10, 19, 35	13, 29, 10, 18	13, 10, 29, 14	26, 39, 1, 40
3	Length of moving object	8, 15, 29, 34				15, 17, 4		7, 17, 4, 35		13, 4, 8	10, 17, 4	1, 8, 35	1, 8, 10, 29	1, 8, 15, 24
4	Length of non-moving object		35, 28, 40, 29				17, 7, 10, 40		35, 8, 2, 14		28, 10	1, 14, 35	13, 14, 15, 7	39, 37, 35
5	Area of moving object	2, 17, 29, 4		14, 15, 18, 4				7, 14, 17, 4		29, 30, 4 34	19, 30, 35, 2	10, 15, 35, 20	5, 34, 29, 4	11, 2, 13, 39
6	Area of non-moving object		30, 2, 14, 18		26, 7, 9, 39						1, 18, 35, 36	10, 15, 35, 37		2, 38
7	Volume of moving object	2, 26, 29, 40		1, 7, 4, 35		1, 7, 4, 17				29, 4, 38, 34	15, 35, 36, 37	6, 35, 36, 37	1, 15, 29, 4	28, 10, 1, 39
8	Volume of non-moving object		35, 10, 19, 14	19, 14	35, 8, 2, 14						2, 18, 37	24, 35	7, 2, 35	34, 28, 35, 40
9	Speed	2, 28, 13, 38		13, 14, 8		29, 30, 34		7, 29, 34			13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	28, 33, 1, 18
10	Force	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12		18, 21, 11	10, 35, 40, 34	35, 10, 21
11	Tension, pressure	10, 36, 37, 40	13, 29, 10, 18	35, 10, 36	35, 1, 14, 16	10, 15, 36, 28	10, 15, 35, 37	6, 35, 10	35, 24	6, 35, 36	36, 35, 21		35, 4, 15, 10	26, 39, 2, 40
12	Shape	8, 10, 29, 40	15, 10, 26, 3	29, 34, 5, 4	13, 14, 10, 7	5, 34, 4, 10		14, 4, 15, 22	7, 2, 35	35, 15, 34, 18	35, 10, 37, 40	34, 15, 10, 14		33, 1, 18, 4
13	Stability of object	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37	2, 11, 13	39	28, 10, 19, 39	34, 28, 35, 40	33, 15, 28, 18	10, 35, 21, 16	2, 35, 40	22, 1, 18, 4	
14	Strength	1, 8, 40, 15	40, 26, 27, 1	1, 15, 8, 35	15, 14, 28, 26	3, 34, 40, 29	9, 40, 28	10, 15, 14, 7	9, 14, 17, 15	8, 13, 26, 14	10, 18, 3, 14	10, 3, 18, 40	10, 30, 35, 40	13, 17, 35

Finally the contradiction matrix, as I told you, there will be a contradiction matrix. So, which inventive principle to use for solving our specific problem, okay. This contradiction matrix really has a 39 by 39 table or matrix, which says that the top 4 most frequently used principles in each box. So, what are the top most 4 principles that are employed by designers to solve the contradiction is listed there.

If there is a contradiction between one parameter and another parameter, what are the most commonly used principles to solve that are listed there, you will be getting the contradiction matrix. So, you can see the contradiction here. Suppose you want to improve the weight of an

object, whatever improve in the sense you want to reduce the weight of a moving object, but then you see that the area of moving object is actually going against your requirement, you do not want to reduce the area, but the area is also reducing when you try to reduce the weight.

So, there is a contradiction, this is the feature you want to change in this direction that is actually going against you, you have to see what are the principles to be used. So, it says that principle 29, 17, 38 and 34 can be used to solve this contradiction. So, any one of these can be tried to solve it. And if you are not able to solve using these principles, it is very likely that you will not be able to solve the weight of the moving object.

If you want to change the force, weight of the moving object and the force, so this you can see, suppose you are trying to improve the weight of the moving object and force is contradicting then you have to use this principle. But if you are trying to improve the force, and the weight of the moving object is going against you, then this would be the principle to be used. So, this way by looking at the matrix you will be able to find out which principle can be used to solve the problem.

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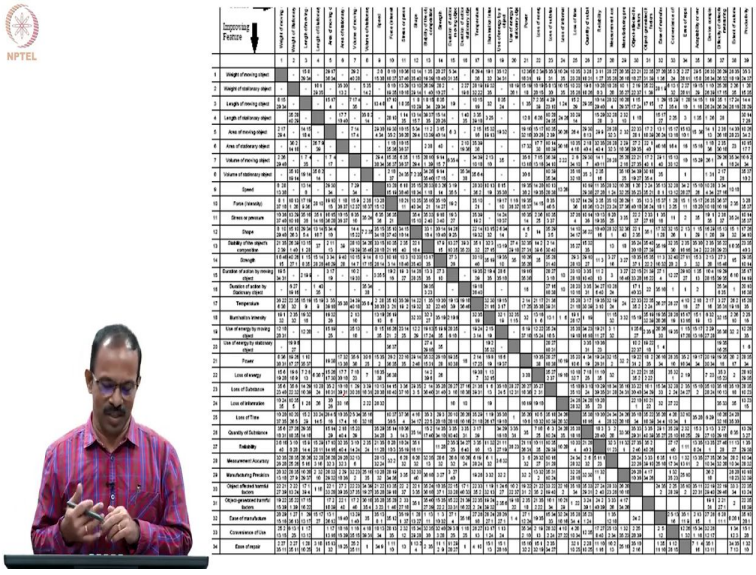

So, this is there in the whole matrix 39 by 39 matrix will look like this. So, this is the whole 39 by 39 matrix just for your information and you do not need to remember this matrix or the

principle to be used can always refer to the standard table and then find out which principle to be used.

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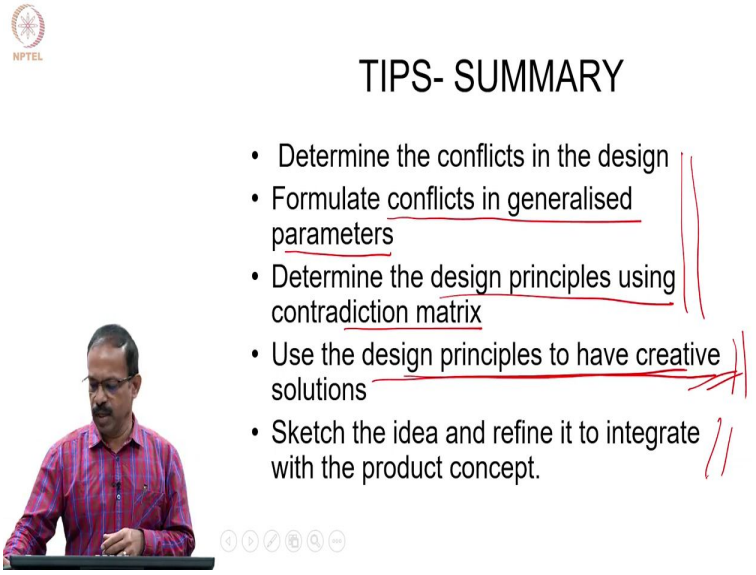

So, I will summarize TIPS and then give one example of how it is used in the practical scenario. So, determine the conflicts in the design, formulate conflicts in generalized parameters. Determine the design principles using a contradiction matrix, use the design principles to have creative solutions. So, this is where actually the design role comes into picture. Because up to here you can actually use the contradiction matrix and then find out the design principle, but then how to use the design principle and how the solution can be arrived at depends on the designer, so creative designer. Then sketch the idea and refine it to integrate the product concept. So, this is the TIPS summary.

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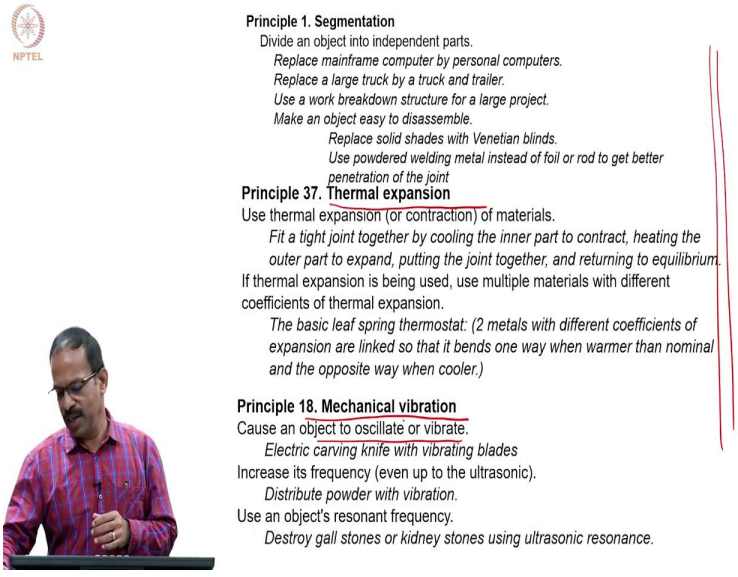

Just take a simple example and then we will stop here. So, you can see an iron box. So, heavy iron to remove wrinkles is the requirement. So, you want a large weight to remove the wrinkles from the iron box. But you want to have a light iron to facilitate the import of the human hand, so when you have a weight that is very high it is very difficult for the person to use it. So, these are the contradictions. You want to reduce the weight of the iron box to make it easy for use but then when you reduce the weight the pressure or the force applied on the cloth is reduced.

So, it actually has a contradiction when you try to reduce the weight. So, the conflict is with regard to the force. So, you want to improve the force on the clothes and then the weight of the moving object also increases. So, when you try to have more force the more weight is needed. So, there is a conflict between these two parameters: force and moving object. Now we will look at the table contradiction matrix and see what is the contradiction existing between ten and two and what are the design principles that can be used.

So, if you look at the table you will see that the principles 8, 1, 37, 18 can be applied to solve this problem, directly to solve this problem. Now principle 8, is the anti weight. So, if there is something weight, it is creating a problem if you try to provide an anti weight, that is you merge

it with other objects which can provide lift, like helium balloon or forms for reducing the weight or providing anti weight.

The other principle of one is basically segmentation. You have to try to see whether you can segment into multiple parts to reduce the weight or thermal expansion, and use thermal expansion of materials. So, you can use the thermal expansion of materials to change the weight. So, if it is a tight joint together by cooling the inner part or contract heating, like this is the thermal expansion.

And then the next one is mechanical vibration. So, can you provide vibration instead of increasing the weight, same weight if you apply vibration, vibrate it you can actually increase the force applied. So, that is another method of, another principle that can be used to solve this problem. So, these are the principles. Now the designer has to see which principle can be used to solve this problem. And finally you will be getting a solution based on that.

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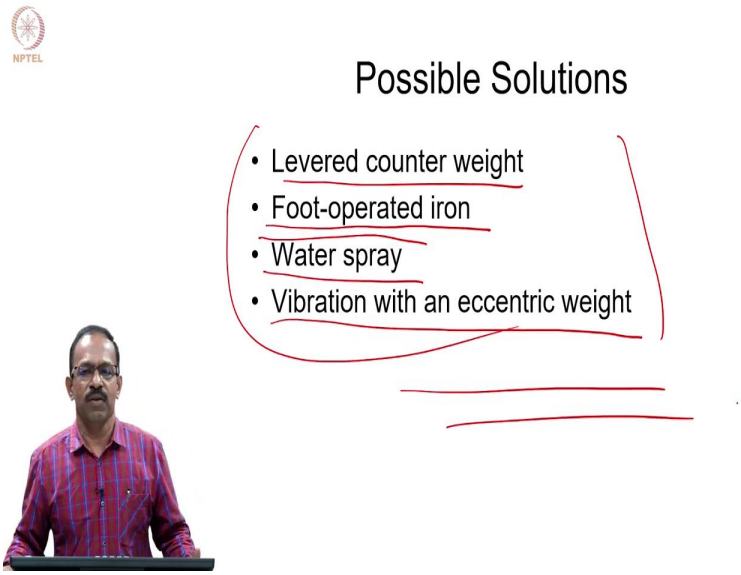

So, the possible solutions are, you can have a levered counter weight, you can have a foot operated iron, we can have a water spray, and you can have vibration with an eccentric weight. So, this is the potential solution. From each design principle you will be able to get a solution. Then you decide which one you want to have, you want to have a foot operated iron so that will

be the, force can be actually be distributed or you do not need to you do not have the problem of the weight acting on the hand or you can have a water spray to using the heat thermal expansion principle can be used to apply the more force.

So, finally you know that the current generation hand boxes use water spray to get the required force on the surface without increasing the weight of the iron box, they are able to provide the necessary force for the clothes to remove the wrinkles. So, that is the potential possible solution. So, that is the way, how we actually get the, how we use the TRIZ methodology to solve design problems.

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So, let me, there are many other examples like this exercise aid for frequent travellers. You can refer to the slide to see how the parameters can be, this principle can be used to solve the problem.

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So, to summarize. So, we discussed the concept generation principles, how the concept generation can be done for solving the design problem, we talked about the intuitive methods and logical methods. So, in logical terms we just talked about TRIZ or TIPS. And then we talked about the mind maps and how the mind maps can be used during intuitive ideas generation sessions.

So, with this I stop the concept generation discussion. So, as I mentioned the ideas need to be converted into concepts and then the design team will come up with 10 or 15 concepts to solve a problem. The next question is out of these 10 or 15 design concepts which one to be chosen for making the prototype and testing. So, that is basically the concept selection stage. So, we will discuss that in the next class. Thank you.