**Health, Safety and Environmental Management in Petroleum and Offshore Engineering**

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**Module No. # 01**

**Lecture No. # 10**

**(FMEA)**

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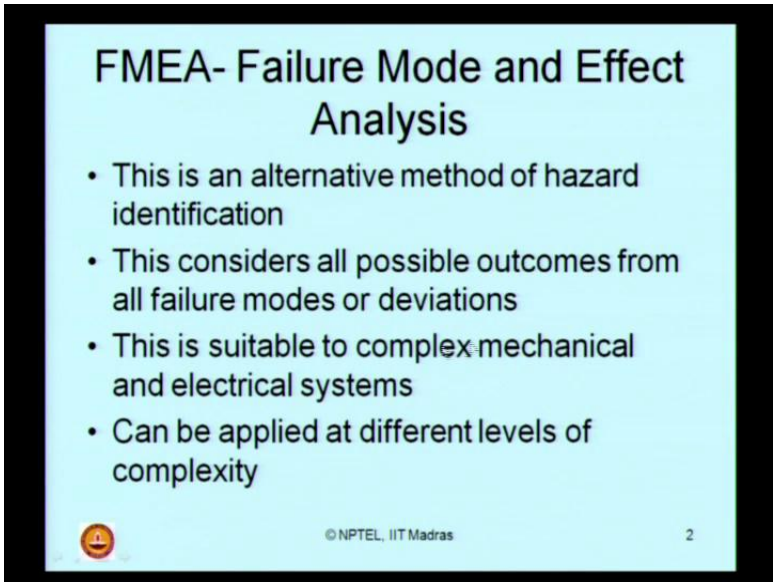


Ladies and gentlemen, now we have the tenth lecture on module one, which is again a method of hazard assessment which I am going to discuss today is FMEA. What do you understand by FMEA? FMEA is abbreviated as failure mode and effect analysis; this is an alternative method of hazard identification. This considers all possible outcomes from all failure modes or deviations. This is suitable to complex mechanical and electrical systems. This can be applied at different levels of complexity.

You can easily recollect that we have discussed one of this method in the last class, that is on HAZOP which can be apply to any process industry. Now, I am discussing another method of hazard analysis, which is actually can be applied to mechanical and electrical systems.

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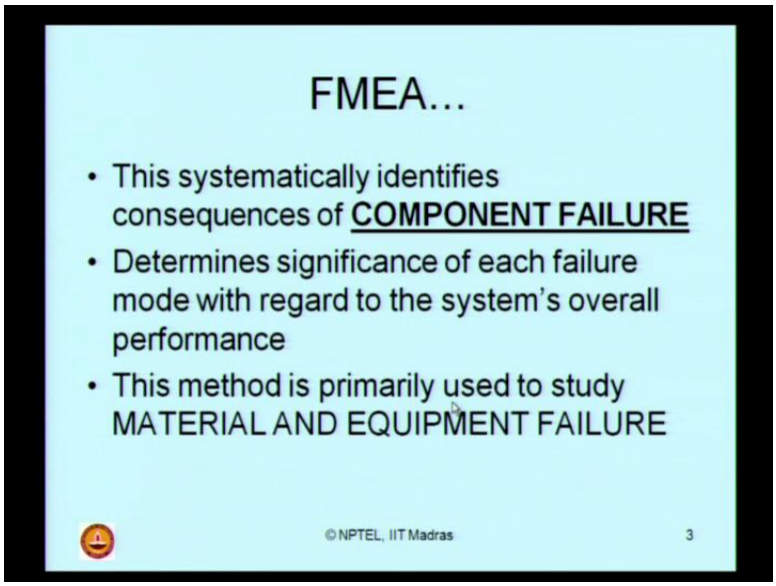


If we look at FMEA, this systematically identifies consequences of component level failure. This determines significance of each failure with regard to the system's overall performance. This method is primarily used to study material and equipment failure.

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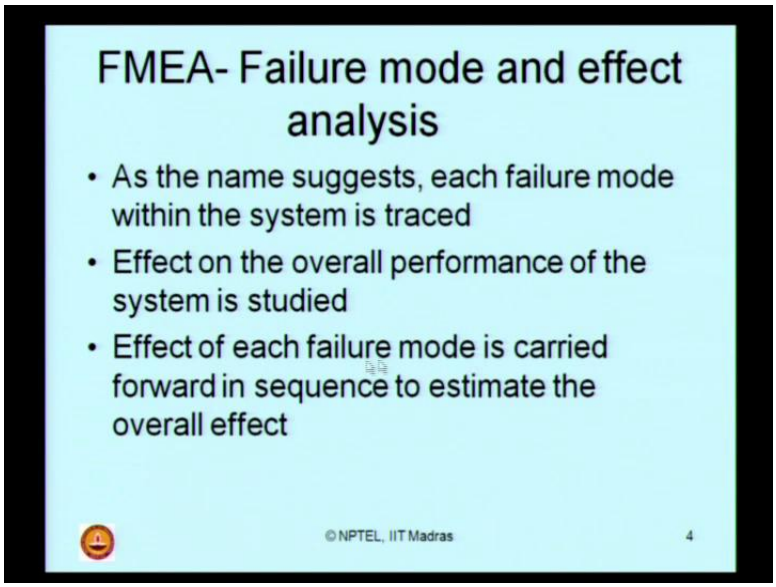


As the name suggests FMEA, each failure mode within the system is traced. For example, you have a mechanical or a electrical system, you tried identify each failure mode within the system. The effect on the overall performance of the system is studied for example, you have a system, you are able to identify one such failure mode within

that system. Now, you are interested to know, what is the effect of that failure mode on the overall performance of the complete system - that is why this is called failure mode and effect analysis.

So, you identify a failure mode for a given system usually it is mechanical or electrical system, for the identified failure mode what is its effect on the overall performance of the system - that is what we analyze. The effect of each failure mode is then carried forward in a sequence to estimate the overall effect. For example, you have identified an mechanical or electrical system in that system you have identified many failure modes not only a single one, there are let us say for example, many failure modes, for each failure mode you find its effect on the overall performance. If there are more than one failure mode, you then you try to identify the sequence of this failure. So that what is the effect of these failure modes, in its sequence to the overall effect of the systems?

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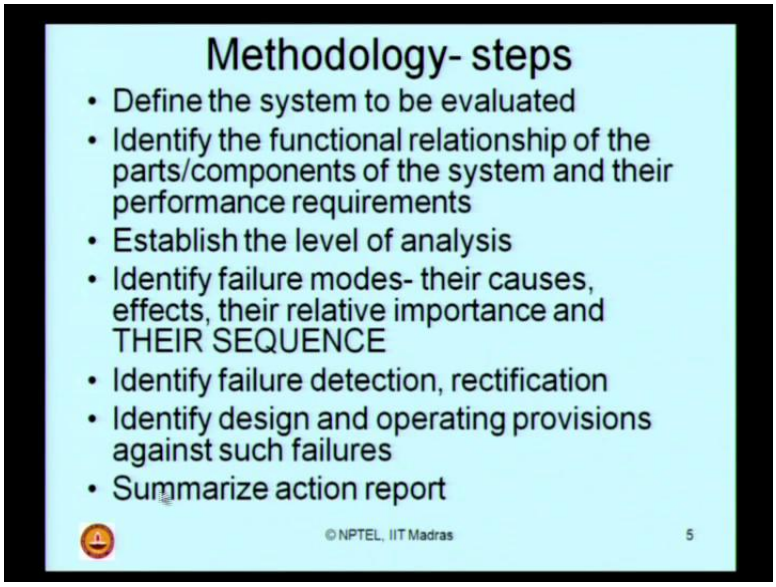


The steps to do FMEA or the methodology is, explained very simple below. First define the system to be evaluated. Identify the functional relationship of the components of the system and their performance requirements. Remember for a given system we are interested in identifying the components and their performance requirements. Then establish the level of analysis what you want. You may wonder, how many levels of analysis exists in FMEA, I will answer this question subsequently in this presentation.

So, let us say, I will try to establish the level of analysis required for the identified system. Then for the given system, now identify failure modes - there can be only one failure mode or there can be many failure modes. You may fundamentally ask a question in mind, if I am saying identify a failure mode for a given system, how do I identify a failure mode, because the given system is a new system? How do we really know in a given new system, which mode will fail or how the system will fail? That is where an engineering knowledge is being employed in doing FMEA. I will come to that in detail by giving you at least three examples to make an FMEA for different systems which I will solve today.

So, for a defined system let us say, I am able to identify all least one failure mode then for the identified failure mode, I am able to locate the cause why this failure mode is happening. The effect if the failure mode occurs what will be the effect in the overall performance of the system and then their relative importance in the overall system - that is what we say consequence. Then identify failure detection, can you detect this failure in advance by means of employing sensors, by means of some mechanical instrumentation, can I detect this failure in advance?

So, identify any such existing failure detection mechanisms and also possibly any rectification mechanism which is advancely available in the system. Then identify a design and operating provisions against such failures. For example, the identified system has got many failure modes; all failure modes necessarily may not hamper the operation. So, identify the design and operating provisions, even if such failure occurs. Once you have done this summarize your action report. So, this is actually the sequence of steps involved in doing an FMEA.

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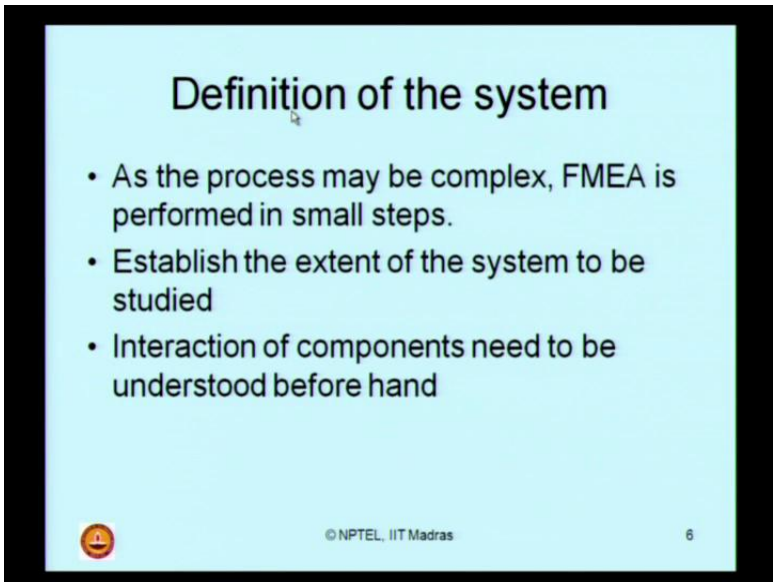


Now, let us define a system, which I am going to consider for FMEA analysis today. What do you understand by definition of the system? You in general as you know, since the process may be a complex task, FMEA is generally performed in small steps - that is a micro level study. So, you establish the extent of the system to be studied. So, the whole system is a very large system and it is very complex. You do not have wished to do an FMEA initially for the complete system. You pick up a segment of the system and try to establish the limitations of this system which you are studying under FMEA.

Then also study the interaction of components before hand; on the other hand, for a system identified by you try to understand the complete working principle of the system in total. So, try to identify different interaction of various components before you start doing an FMEA for an identified system. For example, ladies and gentlemen, if you do not know, how the mechanical working principle of the system is I am sure you will not be able to actually identify the interaction between the components present in that system. So, you have definition means you have got to understand the working philosophy of this system in total.

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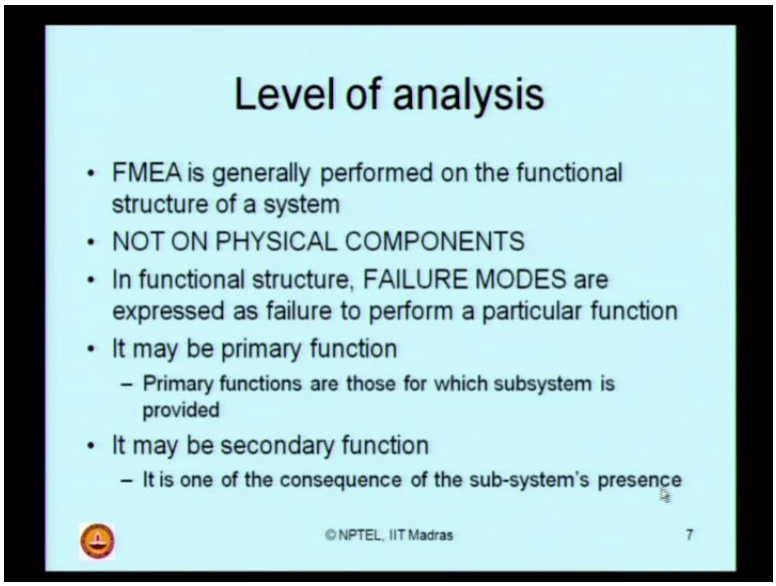


Let us talk about the level of analysis I mentioned in the previous slide. FMEA is generally performed on the functional structure of the system. It is not done on the physical components of the system; please remember this sentence very carefully. I am repeating this sentence again. I have identified a system, the system is a mechanical or a electrical system; you have got many physical components, many physical parts present in the system; FMEA does not analyze the physical components of the system, then what FMEA does? FMEA does the functional study of the components of the system. Remember that it is a functional level analysis; it is not a physical level analysis.

So, in a functional structure, failure modes are expressed. For example, you have a physical component; you know the functional feature of that component. If that feature does not work properly then I can call that as a failure mode. So, failure modes are expressed as failure to perform a particular function.

Ladies and gentlemen, you can easily compare this scenario with what we discussed in hazop. In hazop study just for recapitulating; try to understand and recollect that it is got two backbones - one is what we called as a design intent, other is what we called as a deviation. Now can we relate what is a failure mode with respect to is it a design intent or it is a deviation. I leave this question to you, you can easily answer this. If you have difficulty get back to me lecture on this module on hazop, and try to understand the difference between the design intend and the deviation then try to understand this

question. For example, the failure mode of FMEA is similar to dash, fill in the blanks of that often hazop study.

Now, identify the failure mode that may be in a primary function. Now what is a primary function? Primary functions are those for which subsystem is provided. Then what is the secondary function? Secondary function as those is one of the consequences of the sub system presence. So, these two are inter related.

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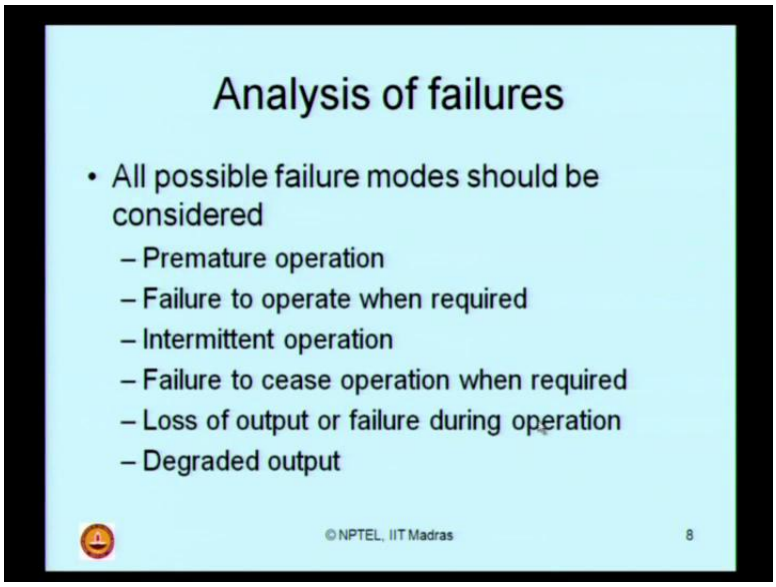


Once you do that all possible failure modes should be considered in your analysis. You may ask me a question, so what are the different possible failure modes which I must considered in my FMEA. I have giving a list of examples here. Premature operation, for example, you want a valve to be open when the temperature reaches t degree Celsius, but is a possibility there the valve may open before temperature is t degrees premature operation failure to operate when required. For example, you have a pressure relief valve which will open and release the pressure, when the pressure inside a vessel reaches let us say ten bar for example.

Now, if the pressure relief valve does not operate despite the pressure reaches ten bar then I can say failure to operate when required. Now intermittent operation, for example, you do not want a specific component to operate at specific temperature and pressure, but still the components start operating physically; intermittent operation or there may be some usual intervention in the whole process, what will be the consequences analysis of

failure of that kind of intermittent operation. Now failure to cease operation when required, now when the temperature drops down to a specific value then the temperature sensor should not work, for example, you should not operate failure, but the question is that sensor is still under operation, so failure to cease operation when required.

Now you have got a sensor, the sensor is supposed to give me an output, but the output is not coming from the sensor loss of output during operation or you may get an output, but it is not desired to the specific quality. So, degraded output all these are different views of failure modes what we put them as different possible failure modes which must be considered in your FMEA.

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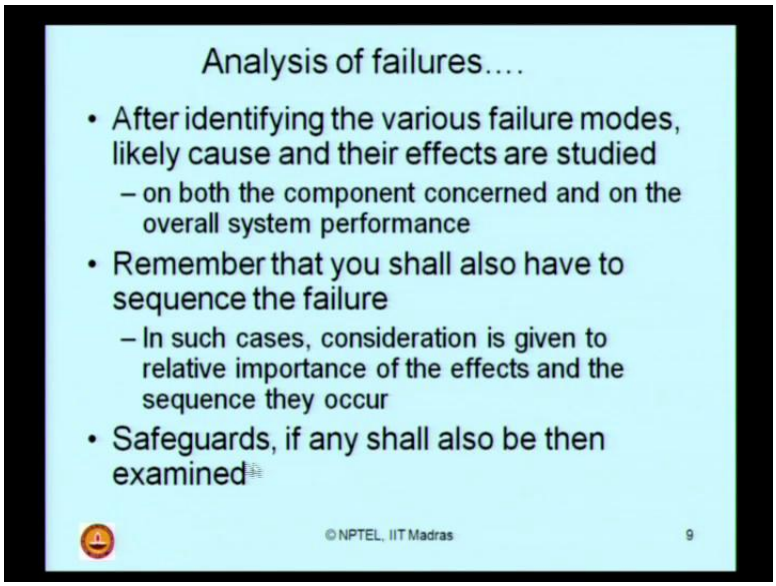


After identifying the various failure modes, the likely cause and their effects are then studied. The cause and effects are studied on the both the components concerned and on the overall performance of this system remember that. I wanted to know what is the cause and effect of failure mode of the component, and what is the sequential effect of that failure of a component on the overall performance of the system that is what FMEA is? So, it starts analyzing the system from a micro level to the macro level. Remember that you shall always have a sequence of failure in your operation. In such cases, consideration is generally given to the relative importance of the effects and the sequence they occur. If you identify in a safeguards in a system, please note that any such system shall then be examined separately.

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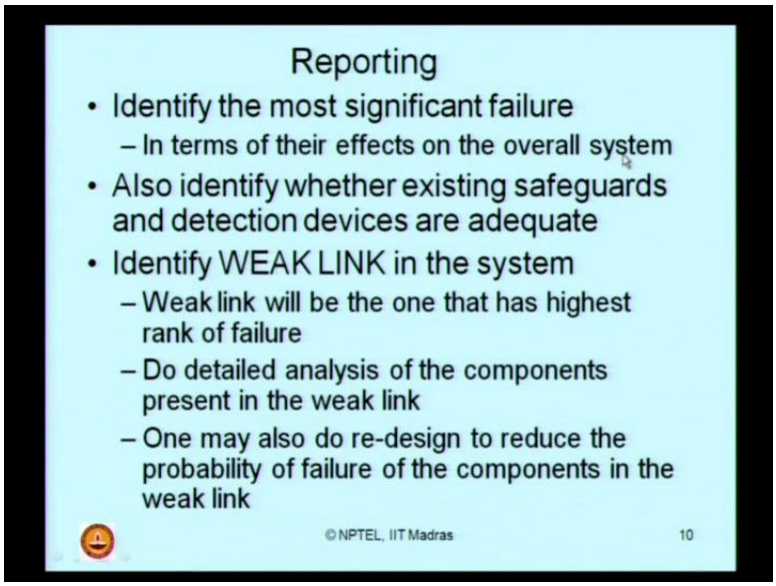


How do you report once you identify all these things? Now amongst the given identified failure modes, now select the most significant failure. You may ask mean the significant respect to what in terms of their effects on the overall system, that is why we said sequential analysis. For example, you have got different failure modes amongst the failure mode one of them is having a very significant effect on the overall performance of the system then identify them in terms of its rank.

Also identify whether existing safeguards and detection devices are adequate to trace such failure in advance. After you do this in a given system identify what we call as a weak link. What do you meant by a weak link? Weak link will be one that has the highest rank of failure, for that weak link do detailed analysis. One may also do the re-design to reduce the probability of failure of the components in the weak link. So, in FMEA, ladies and gentlemen, we have one of the meritorious advantage of the system analysis is that in a given system after identify different failure modes one can really narrow down to what we call as a weak link in the given system.

So, if you are able to identify the weak link, then try to do a detail analysis only on the weak link components or try to re-design those components. So that the performance level of the overall system can be increased.

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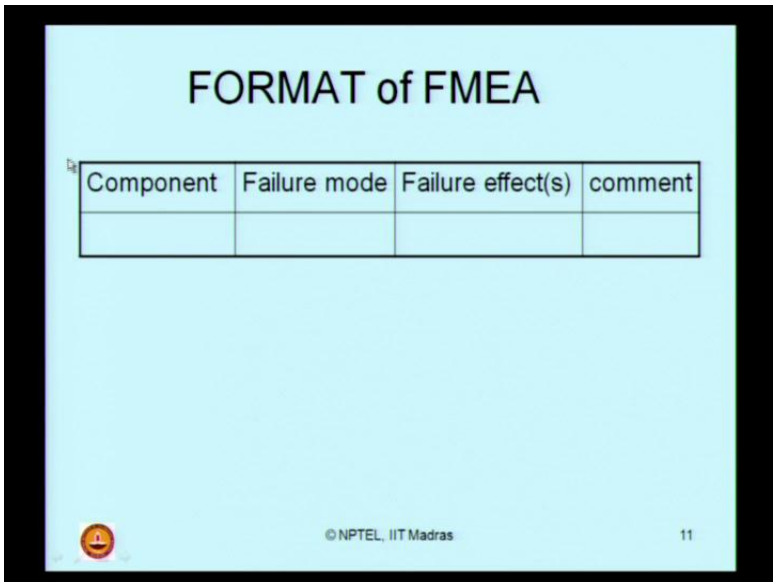


Now you may wonder, what is a format by which I can report FMEA. It is a simple tabular column format; you must identify the component, you must specify the failure modes or mode of that component, what will be the effect of that failure mode on the overall performance? Therefore, you start commenting it. I have got an example where I will fill up this column slightly in a more descriptive manner.

We will now discuss one example of preparing FMEA for a passenger car. This is basically a design FMEA where I have got a model of a passenger automobile, where I want to see how can we apply the failure mode effect analyze study for this problem; watch this video. (No audio from 16:18 to 16:39) So, what we understand from this is I had a car the car was going at a specific velocity, because of the road surface had some skid problem the brake was suddenly applied to the braking system device had been applied to the vehicle. Now, what will be the effect of this kind of design in FMEA we will talk about that now with an illustrated example.

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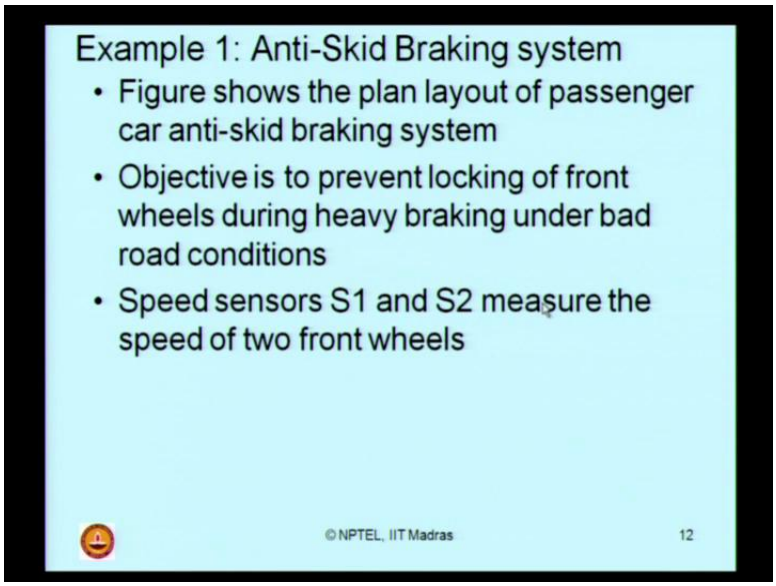


We will explain now the anti-skid braking system which we just now show a video. Now the figure below which was showing you is actually is a layout of passenger car of an anti-skid braking system. The objective of this study is to prevent the locking of front wheels during heavy breaking under bad road conditions. Now, there are two sensors speed sensors S 1 and S 2 which is present and measure the speed in the front wheel.

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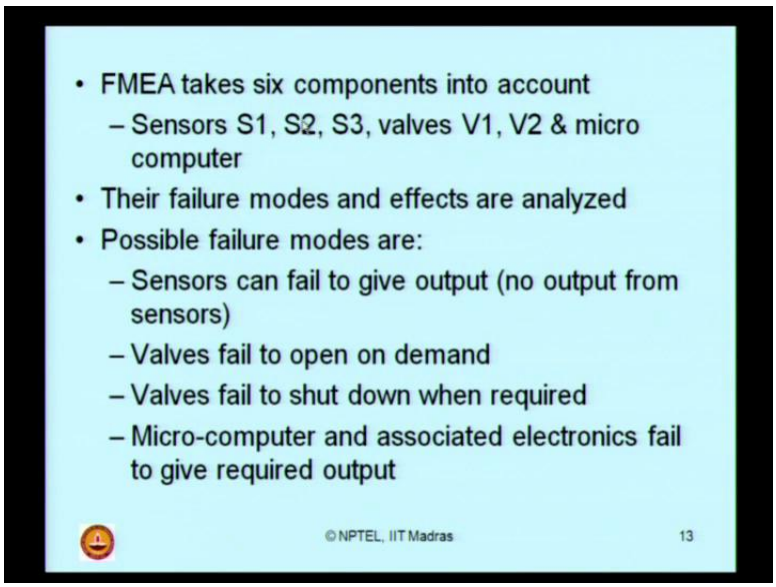


The FMEA now considers six components into account sensors S 1, S 2, S 3 and valves V 1, V 2 under micro computer. Now these failure modes and effects are analyzed now

using a design FMEA problem. Let us now look at what are the possible failure modes that can occur in this problem the sensors can fail to give an output for example, S 1, S 2, and S 3 are the sensors located in the front wheel and the driving shaft respectively. This has to supply a signal system to my micro computer, but there is no output coming from the sensors, that can be one possible failure mode.

The second can be the valves fail to open on demand the valves V 1 and V 2 should open, so that the driving shaft is controlled obviously, but sometimes there may be an erroneous or the spurious system of working of this valve, the valves do not open on demand. On the other hand, there can be a possibility that the opened valves do not also close when they are required to be closed, because the speed is got to be anyway maintained in the car.

So, the valves do not close is also an option of a failure mode, and ultimately the signals comes from the sensors in the valve mechanism is operating successfully, but still the micro-computer and associated electronics may fail to give the required output, so that the valves are not controlled properly and effectively by the micro computer. So, you have got different failure modes analyzed from the passenger car system, which is for an anti skid braking system as demonstrated in the video.

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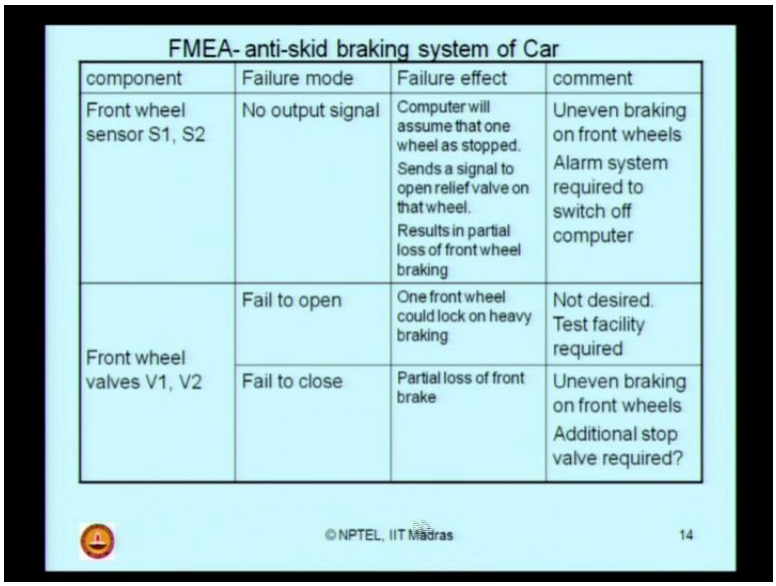


When you looked at the FMEA anti skid braking system of the car, you have got this table being filled up very comfortably.

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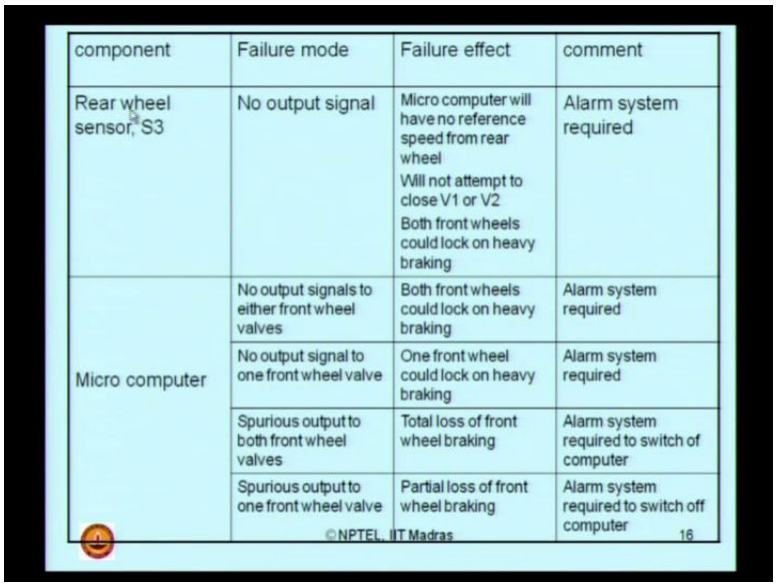


Let us say talking about the rear wheel; I avoid this sensor S 3. The sensor S 3 of this rare wheel does not generate an output. So, in that case, micro controller will have no reference speed from the rare wheel at all. So, it has no idea what is a speed of the driving shaft and the rear wheel therefore, it will not attempt to close the valve V 1 and V 2 because it is having no signal from S 3 at all. So, both front wheels could lock on heavy breaking, it will jammed the vehicle.

So, in that situation when any sensor is not working, I must have an alarm system. Talk about the micro controller or micro computer, no output signal is generated either from the front wheel valves or from the sensors. In that case, both front wheels may be jammed or may be locked because of heavy breaking. You need an alarm system to control that kind of situation. No output signal is coming from one of the front wheel valve, let say one wheel will get blocked you have an uneven breaking therefore, alarm system is required.

Spurious output to both front wheel valves for example, the front wheel valves do not open or should not open at a specific demand time, but they open, so spurious output. So, total loss of front wheel braking will occur alarm system is required basically switch of the computer. Spurious output of one front wheel valve in that case partial loss of front wheel braking will occur. So, alarm system is required to switch of the computer. So, remember when you identify the components look at the possible failure mode of each of

the component and try to see what is the effect of failure mode of each of the component of the overall performance of the vehicle then try to give your comment.

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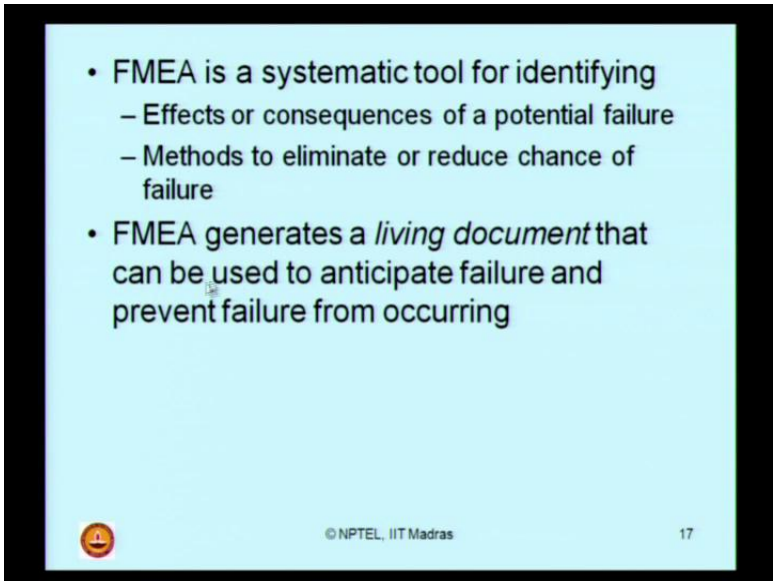


So, therefore, FMEA - failure mode effect analysis is a systematic tool for identifying the effects or consequences of a potential failure; methods to eliminate or reduce chance of failure is through FMEA. FMEA generates what we call as a living document that can be used to anticipate failure and prevent failure from occurring.

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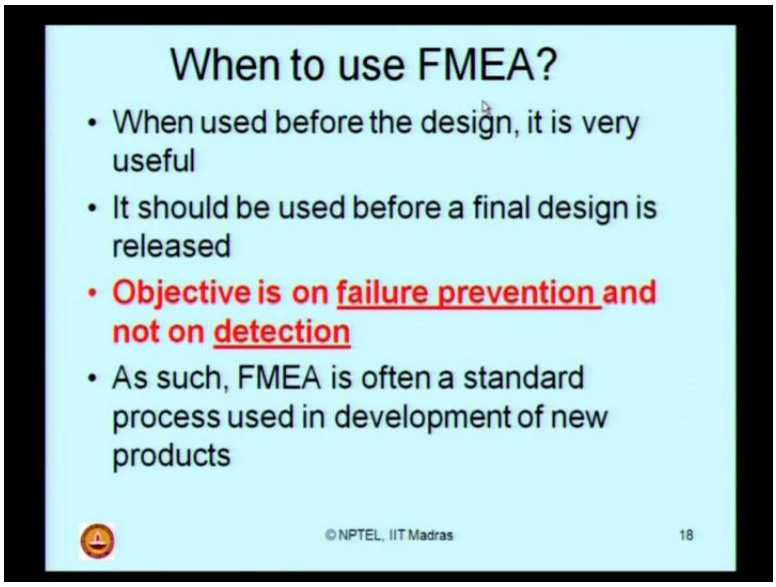

Now, a very interesting question is asked, when to use FMEA? When should I employ FMEA in my study? When used before the design generally it is very useful it should be used before a final design at least is released the objective of FMEA is on failure prevention and not on failure detection remember that as such FMEA is actually a standard practice used in development of new products. So, whenever you launch a new product either at the design stage or at least at the release of the final design FMEA is generally done to check the possible failure preventions in the system rather than detecting the possible failure.

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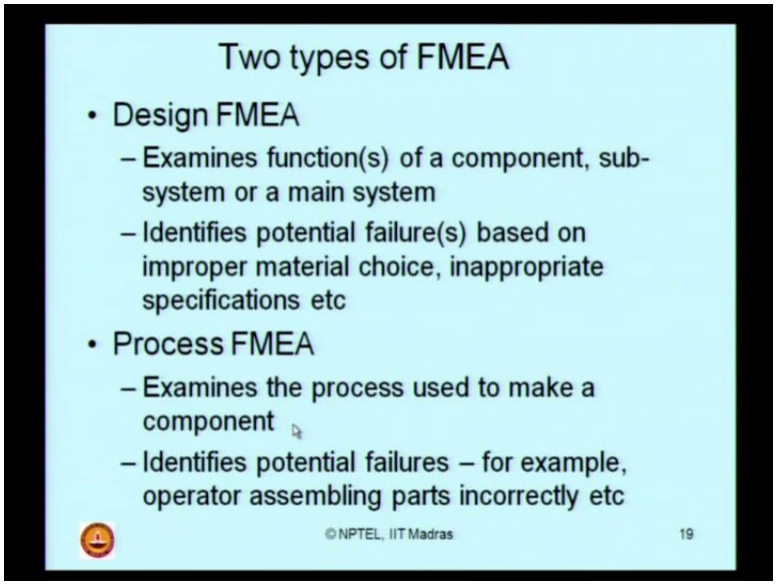


There are two types of FMEA one can perform, one is what we call as a design FMEA - this examines the functions of a component, the sub system or a main system subsequently identifies the potential failures based on the improper material choice inappropriate specification etcetera. The other type of FMEA could be the process FMEA; it examines the process used to make a component, it identifies potential failures. For example, the operator assembling parts incorrectly can be a part of observation from a FMEA study.

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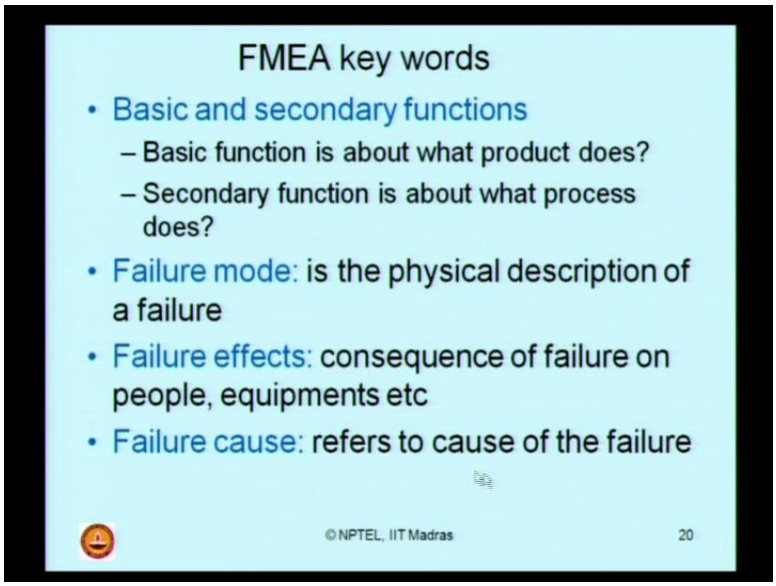


Again FMEA like HAZOP has keywords. Basic and secondary functions what is a basic functions basic function is about what the product does, secondary function is about what the process does. So, one is a design intend, other is a deviation. So, that is what comparable with HAZOP study as well.

What is a failure mode? Failure mode is the physical description of a failure. You have got a physically described how a component will fail to perform its intended function. Then what is a failure effect failure effect is nothing but the consequence of that failure on human safety may be on people may be an equipments etcetera. Then what do you understand by a failure cause, this refers to what is the reason this failure had occurred cause of the failure.

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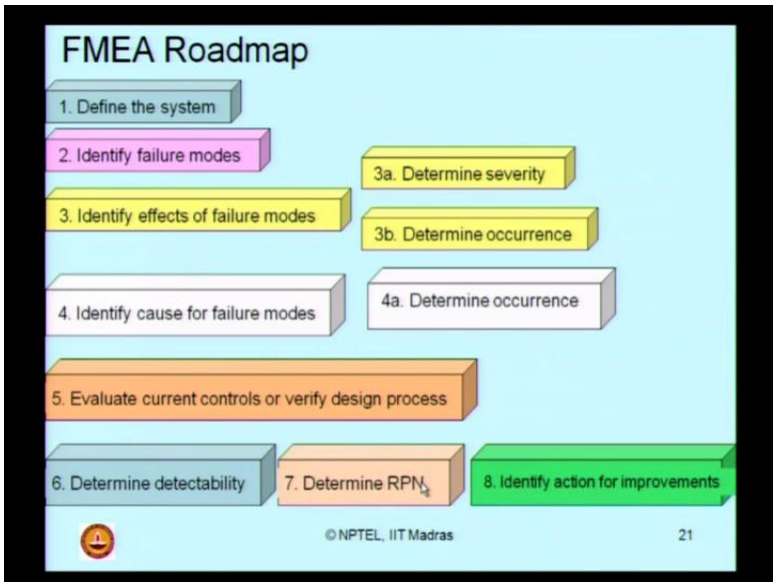


When you look at the FMEA roadmap, let say I want to look at how I can prepare an FMEA for a given component or a given product as a design level or process level, what are all the steps I must follow to get into the FMEA analysis in complete.

First of all define the system or which we are going to perform the analysis, then identify the different failure modes in that system. Then identify the effects of the failure modes in that system. Once you identify the effects then you will know what will be the severity and what is the occurrence of the system. Remember risk is something you do with this two. Identify the cause for failure modes once you identify the cause also determine the occurrences of that failure modes, then evaluate the control measures what you currently have or verify the design process to introduce any such control measures in advance. Then determine what you called detectability.

What do you understand by detectability? You already have identified some failure modes now here try to see whether you can detect this failure modes some of them in advance once you do that try to identify and find out what is the risk priority number. As I told you the failures can be consequential the effect of any specific failure or any specific failure mode on the system may not be same may not be equal for all failure modes, one failure mode be severe consequence in the system other may not have.

So, try to prioritize the risk by giving what we call as a risk priority number. So, remember that the qualitative features of failure mode are now slowly getting converted

into quantitative numbers by means of what we call as risk priority numbers once we get in RPN then identify the action for improving the risk involved or the hazards present in the systems.

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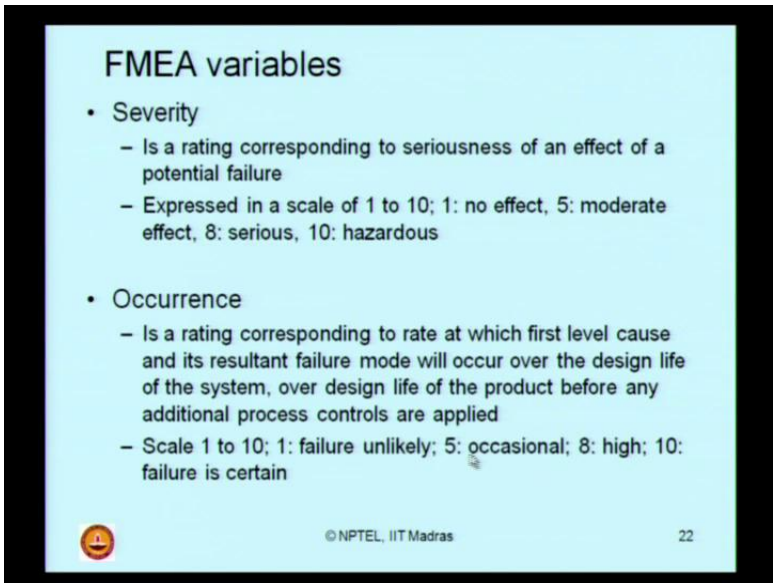


Now, let us talk about what is FMEA variable? Severity is one variable, it is actually a rating corresponding to seriousness of an effect on a potential failure. So, I express this severity in a number on a scale of one to ten on a ten point scale basically. On the other hand, if a give a number one to any severity, I say it has no effect on system at all. If you give a number ten to any severity, then I should say it is very hazardous for that system

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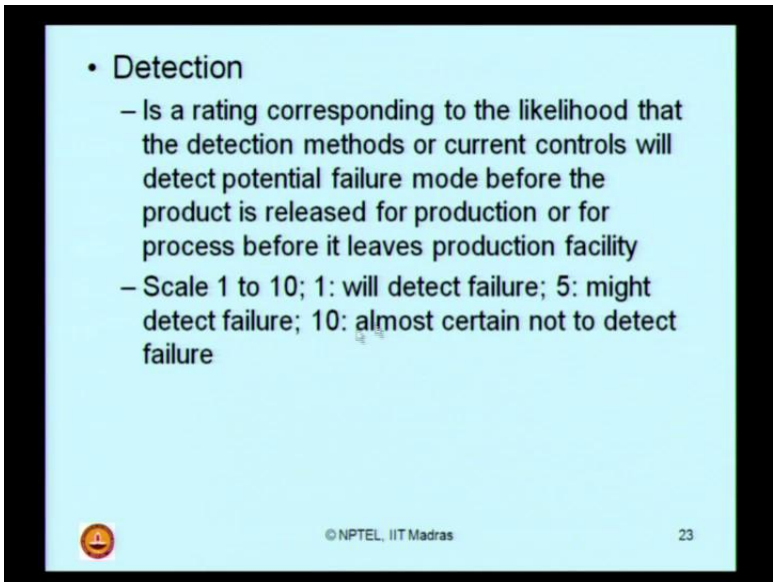


We talk about occurrence again it is a rating corresponding to the first level cause, and it is resultant failure. What is the first level cause of any specific failure, which will occur in the design life of the system or the designed life of the product before any additional process controls are applied? Again this is given in a scale of one to ten one is the failure is very unlikely, it will not occur or ten means the failure is certain it will definitely occur. So, what we have guarantee that the failure of the identified failure mode will occur, that is what we speak about here in a ten point scale; one means unlikely and ten means certainly going to occur.

Let us talk about detection, again it is a rating correspond to the likelihood that the detection methods or the current controls will detect the potential failure before the product is released for production or the process before it leaves production facility. So, what are all the control measures existing a new which you can add to detect the possible potential failure? Again this on a ten points scale - one means for certain detect failure, ten means almost certain not to detect the failure. Simply give a number from one to ten, and you can subjectively vary these value one means less will detect failure, five means it might detect failure, ten means for sure it will not detect failure at all like that

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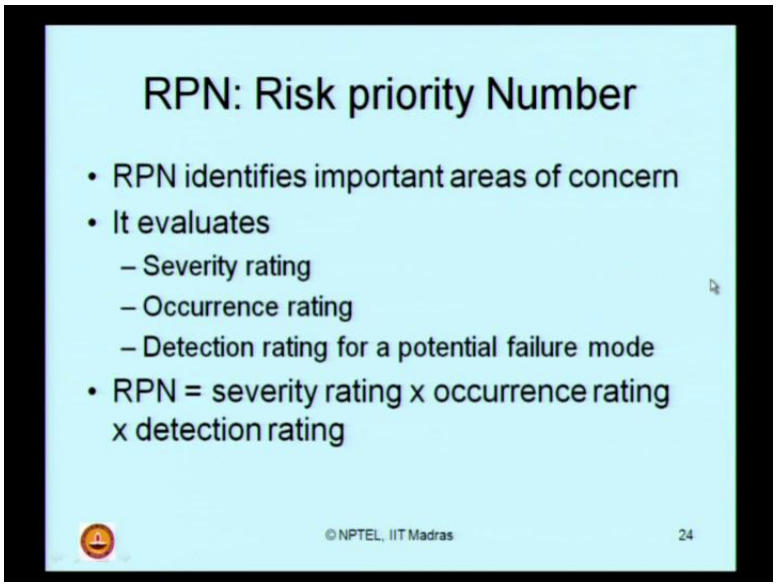


Once you have these three variables severity, occurrence, and detection then you calculate what we call as risk priority number - RPN. Risk priority number actually identifies the important areas of concern. It evaluates a severity rating, the occurrence rating, and the detection rating for a potential failure mode. So, RPN is actually a product of these three. So, if you know the severity rating, the occurrences rating, and detection rating simplifying the risk priority number. All of them as the ten point scale subjective values as I showed you in the previous slide.

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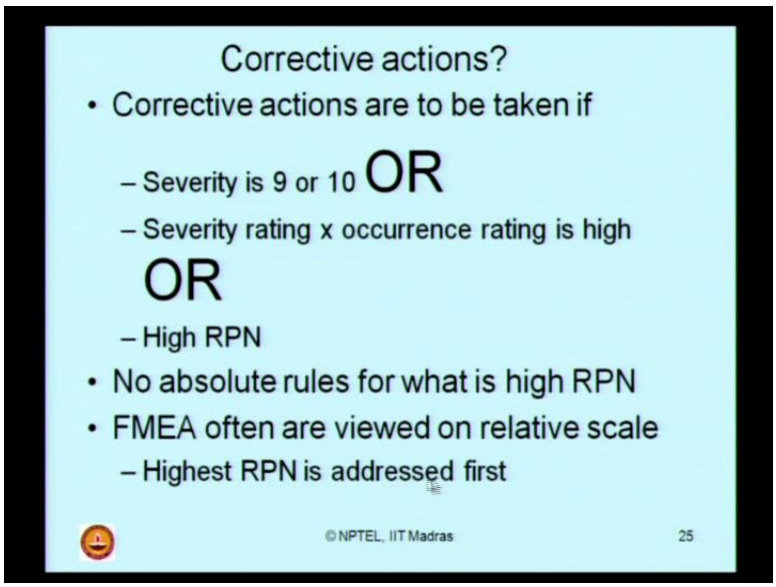

What do we understand by corrective actions? Corrective actions are to be taken if the severity is 9 or 10. If the severity what you identify on a ten point scale is 10 or 9 then you must take corrective measures. Or severity rating into occurrence rating is high, for example, both of them I measure in ten point scale you get the product of these two, then if that product comes to be high then you take corrective measures. Or if you get an high risk priority number then also you initiate corrective actions, but unfortunately ladies and gentlemen there are no absolute rules to say what is something called high risk priority number, there is nothing like that high and low, FMEA often are view on relative scale. So, the highest RPN is first address in the analysis.

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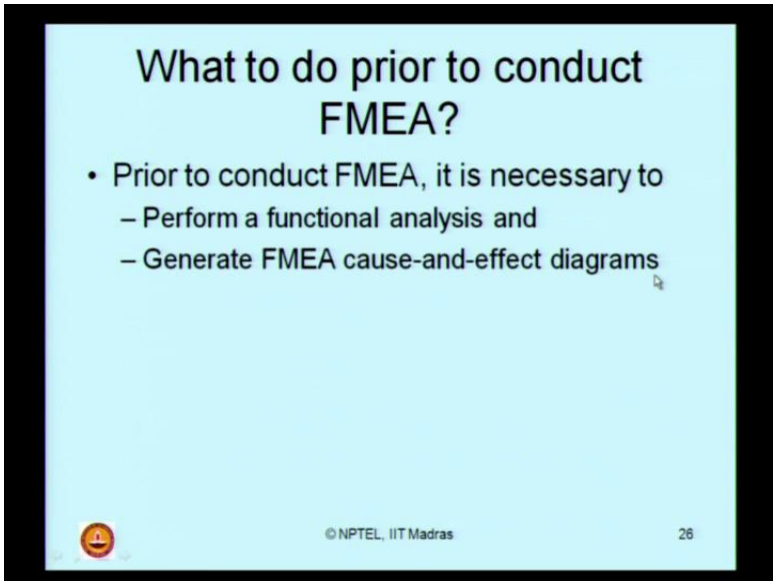


What to do prior to conduct FMEA? Before you start an FMEA, what to do or what all you got to do? Prior to conduct an FMEA, it is necessary to perform a functional analysis and then generate what we call cause and effect diagrams.

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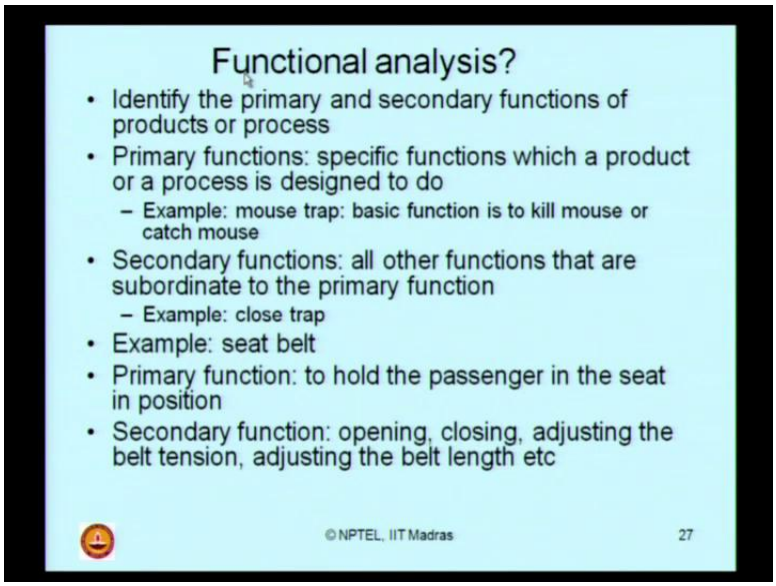


Let us see how we can do a cause and effect diagram for a functional analysis. Let us fundamentally ask a question, what do you understand by the functional analysis? Functional analysis is a process by which we identify the primary, secondary functions of products or the process. The primary functions are those specific functions which a product or a processes designed for. For example, let us take a mouse trap. The basic function of the mouse trap is to kill the mouse or at least to catch a mouse. So, that is a primary function of a component which is a mouse trap. Then what is the secondary function, all other functions that are subordinate to the primary function are called secondary function. Once this example for mouse trap is closing the trap, opening the trap etcetera. So, closing a trap can be called as a subordinate to the primary function therefore, I can call this as a secondary function.

For example, let us say I have a seat belt in an automobile vehicle in a passenger car. Can you identify, what is the primary function or what are the primary functions of a seat belt? And what are the secondary functions? Let us say the primary function is to hold the passengers in the seating position. The secondary function could be opening the belt, closing the belt, adjusting the belt tension, adjusting the belt length etcetera. So, if you identify a specific component you can do easy functional analysis which is essentially to be done before you do an FMEA. And function analysis divided into two parts you have to identify the primary and secondary functions of the components.

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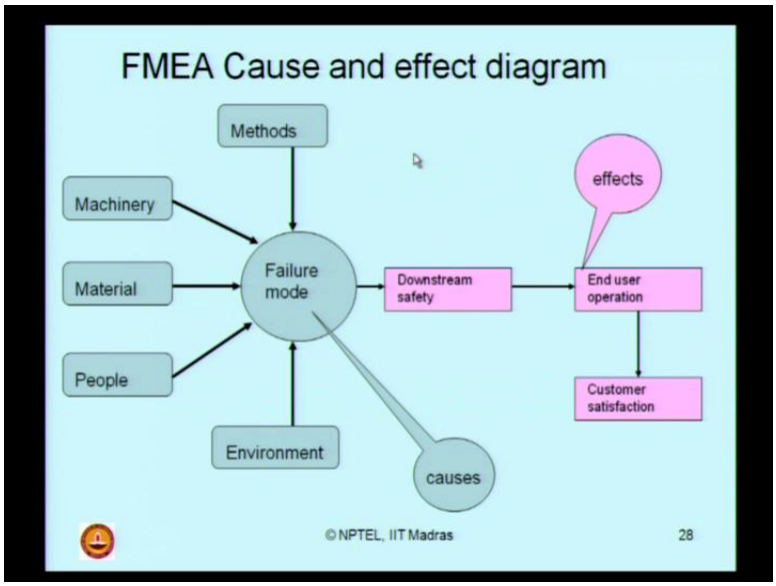


Let us speak about what is called cause and effect diagram? If you are able to identify a failure mode, what are the machinery, material, people, environment, and methods contributing to the failure mode. You have got to identify that is why we call what are the causes resulting from methods, machinery, material, people, and environment which causes failure. Once you do that then what is the downstream safety of that failure mode, what is the end user operation on that failure mode, and what is the customer satisfaction on the failure. So, these are all what we call as effects, these are all what we call as causes.

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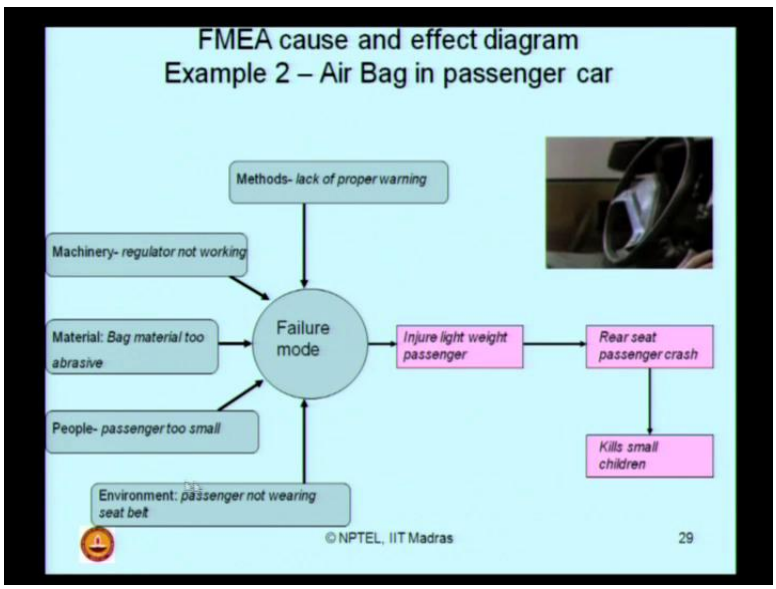

Now, I want to identify or prepare a cause and effect diagram to perform an FMEA on an air bag in a passenger car. Ladies and gentlemen, all of you know what is a function of an air bag? So, look at this video very briefly, you will be able to easily identify the primary and secondary functions of the air bag system in a passenger car. Let say for example, this is an air bag which is coming forward from the steering wheel, if an vehicle have to have impact low, so before the present hits the dashboard, the airbag protects the person. If you do not have an airbag, the person hits his head on the steering wheel or the dash board like this. So, an airbag the primary function of the airbag is to protect the head on injury on a passenger, driver who is driving the car.

So, what are the methods lack of proper warning. Machinery the regulator is not working in this given system. What could be the material problem, the bag material is to abrasive it actually irritates the person who is aborting the airbag. What can we do about the people the passenger is too small, for example, if you have enough height of the passenger then the head come and rest in the airbag if a small child is driving the car then the head of the child will not even reach the airbag even though the airbag is in position. Then what is the environmental effect on that let say the passenger is not wearing a seat belt the whole bodily movement will take place whereas, the air bag is only to protect the head and not the remaining parts of the body. So, these are all what we call different failure modes.

What will be the effects of them? Injure a light weight passenger, for example, the passenger is light in weight he bodily moves and that injures light weight passengers, because the air bag is having specific pressure which is maintained inside that may hit back the passenger. Rear seat passenger can crash, because the air bag is provided only for the front seat passenger, the driver or the next to him; in the rear seat passenger can crash anyway. And if you have small children either driving or sitting at the back, it may possibly kill them. So, what are all the effects of the failure modes analyzed, what we call as causes and effects diagram.

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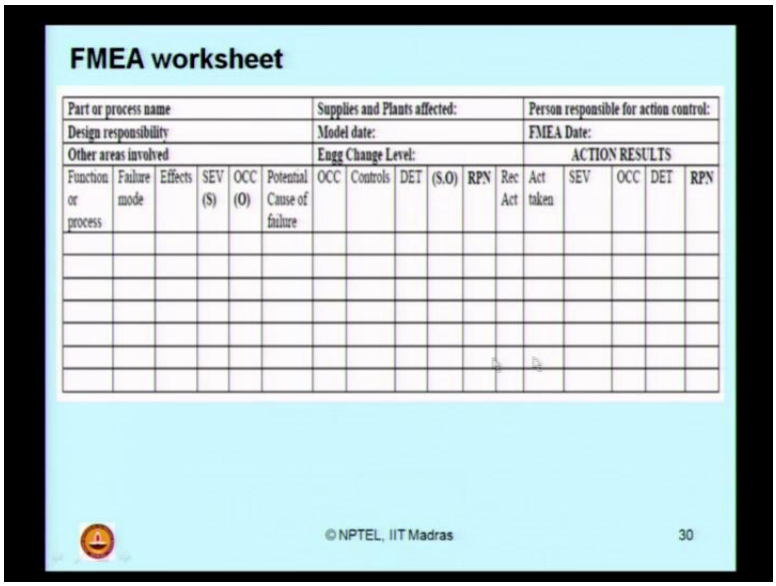


So, we have an FMEA worksheet, where I am going to write down the function or the process, what are all the failure modes, what are the effects, what is the severity, what is occurrences of that failure mode, what is the potential cause? I try to give them in terms a number, try to multiply these three and try to find what we call as an risk priority number. Then I recommend certain actions to reduce the severity, how to reduce the occurrences, auto detect this in advance. Once I do that after the actions are taken what will be the new numbers on severity, occurrence, and detections therefore, what is the new risk priority number. So, what is the risk RPN after the actions are taken, and what is an RPN before the actions are taken; that is what I am going to enter in my FMEA worksheet.

Thank you.