Health, Safety and Environmental Management in Offshore and Petroleum Engineering

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Module - 02
Operational Safety
Lecture - 22
FMEA-example

Welcome friends to the 22nd lecture on HSE practices in offshore Petroleum Engineering in module 2.

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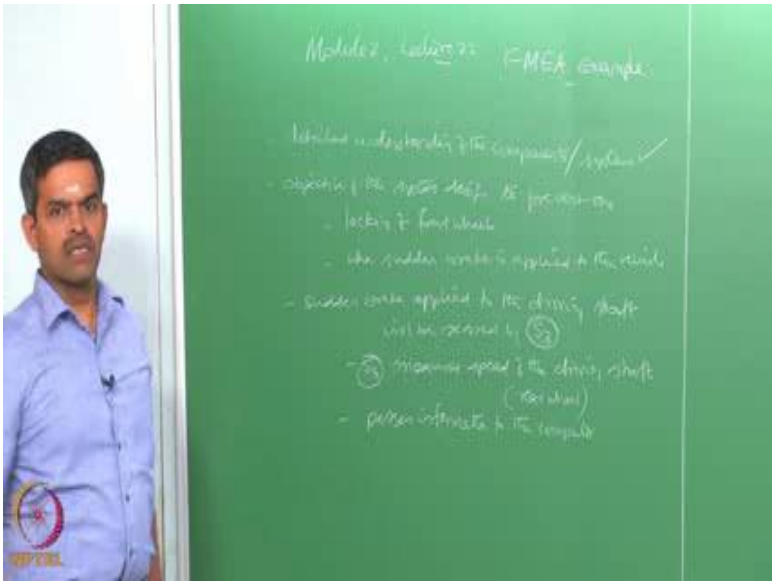

We will see an example on FMEA study in this lecture. We already said FMEA is one of the methods which are helpful in identifying the hazards present in a electromechanical systems. There are certain requirements for performing FMEA, which will discuss as the example goes ahead. FMEA is generally reported in a standard format which we discussed in the last lecture.

So, we have to identify different failure modes and the causes for these failure modes, and if they fail the perceived failure what would be the consequences on the component,

as well as in the overall performance of the entire system, and the system have any safe guard which can compromise or which can counter act on this consequences. Then we have account for those safe guards present in the system and ultimately one can give recommended actions. So, overall performance of the system you completely improved by either altering or re designing the components present in the given system. So, please pay attention to the graphical image shown on the screen now.

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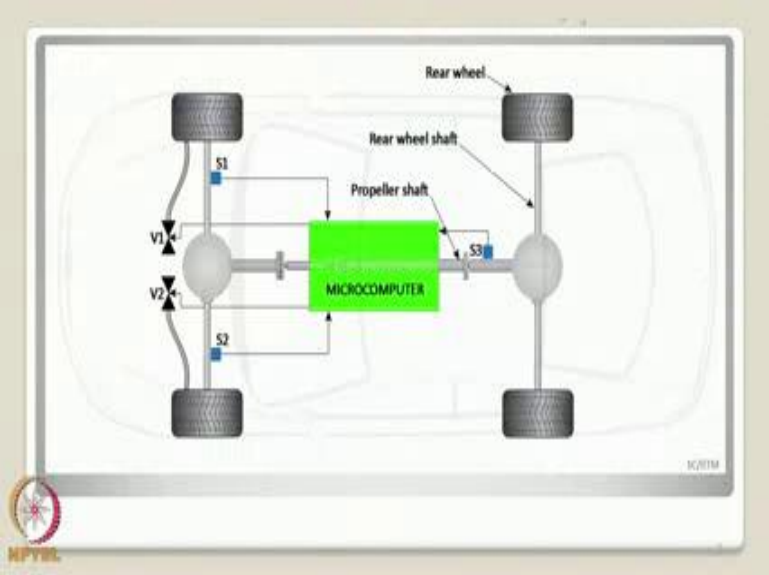

We are taking a very simple example just everybody can understand this FMEA very quickly, because it needs a mechanical system to understand. So, we have taken an automobile model. The automobile model is shown in the gray sketch here, passenger car which has got four wheels. As you see here in the black here this is the front wheel this is the rear wheels these are driving shaft this is a rear wheel shaft this is what we call as a propeller shaft in the design, and this is micro controlled sensors are located on the four as well as the rear wheel shafts. There is a sensor s 3 located here which is connecting the driving shaft to the propeller shaft. And the 4 wheel shaft has two sensors s 1 and s 2, which will be actually feeding information to the central micro computer which gets information from the sensors s 1 s 2 and s 3, as well as, the micro computer will now control the opening and closing of the valves v 1 and v 2.

So, that is the mechanical functioning of the whole arrangement for which we are going to write the FMEA work sheet now. Let us quickly see the working of this for example, this being a driving shaft, when the speed of the vehicle is very high, which is indicated by the sensor connected to the propeller shaft which receives this shaft speed from the rear wheel, then when the brake is applied you know there is going to retardation in the driving shaft speed. So, that will be sensed by s 3 which being information to the micro computer.

The micro computer will now say that the driving shaft speed as we reduced and this is an extensive brake being applied. If the reduction is sudden it will alert the sensors s 1 and s 2 which will open the valves v 1 and v 2. The moment is valves are opened by the control mechanism operated by the sensors s 1 and s 2 then; the breaking power applied on the driving shaft is reduced. Therefore, the shock which is expected to happen on the car, because of the sudden brake applied on the driving shaft will be now released, because the valves will open and the breaking energy will be relaxed and released, and then driving shaft will receive less retardation because of the applied brake.

Subsequently when the brake comes to normal position the sensors s 1 and s 2, react that feeds back to the computer and the micro computer again closes the valve v 1 and v 2, through the sensors s 1 and s 2, and the vehicle goes ahead. So, the very purpose of this particular system which is having sensor controlled mechanism of s 1 s 2 and s 3 is that, when the brake is applied suddenly, this will cause damage to the passenger in the car. We want to relax this sudden impact caused in the vehicle by a sudden brake which is now controlled by opening and closing of the valves v 1 and v 2, this being the function of the whole system.

Let us now look at the objective of the whole problem. Now the objective of the problem is to prevent, so, let say detailed understanding of the components and the system is carried out. So, let us quickly see what actually we are looking at the objective of the system design as expected, is to prevent the locking of the front wheels. When this locking will occur, in general this will occur when sudden brake is applied to the driving shaft. How it is done we already saw, that the sudden brake applied to the driving shaft will be sensed by the sensor s 3. The sensor s 3 measures actually the speed of the diving

shaft this also indicate the speed of the rear wheel of course, it passes information to the micro computer.

Micro computer present on board the micro computer then indicates the speed sensors.

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It now controls the speed sensors s 1 and s 2 located on the front wheel shaft to open or close the valves v 1 and v 2 that is the function. Now if the speed of the vehicle for significantly low, if the speed falls significantly low, because of the sudden brake valves v 1 v 2, should open which will be controlled by the sensors s 1 and s 2, once these valves are opened the breaking force will be reduced. So, there is the whole action. What we are understanding from the mechanical system which is been shown to you on the screen. Having said our job is to find out the components now FMEA is a component level analysis.

So, FMEA need to identify in step number 1 the first set of components which need to be analyzed. And their inter relationship which is qualitative now the components here are sensors s 1 s 2 s 3 and valves v 1 v 2 then of course, the micro computer. We have taken a very simple example to really illustrate how FMEA can be easily carried out for this problem. We will take one more example later, which will be relevant and which will be

slightly complicated compare to this using a cause and effect diagram we will talk about that, to identify the components in step number 2.

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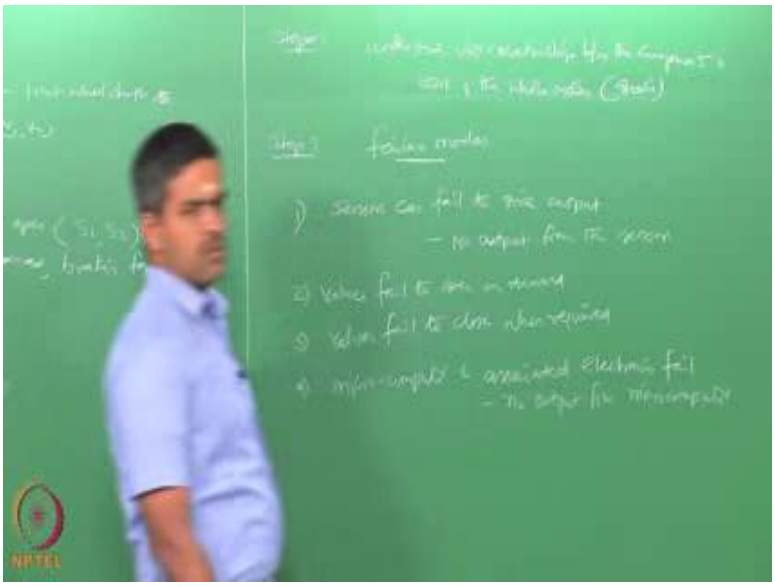

We have understood the inter relationship between the components and that of the whole system which is also a qualitative.

In step number 3 we have to identify the failure modes, we already discussed in the last lecture. What are the possible failure modes which could happen or perceived in electromechanical systems. Let say the first one could be sensors can fail to give output that can be the first failure mode that is no output from the sensors that could be the first case. Second could be valves fail to open on demand. We already know the valves v 1 and v 2 are controlled basically the opening and closing of this valves are controlled with the sense s 1 and s 2, there is a possibility that the sensors s 1 and s 2 sends the signal, but there is a mechanical fault in the valve.

The valve fails to open when it is require to be opened similarly once the valves are opened, obviously, the speed will improve or the breaking force will decrease comfortability will be reach and once it is reached, the valve should close automatically by the control mechanism of sensors s 1 and s 2. But there can be a failure mode where

valves fail to close when required, as long as the valves remain open, their breaking force will be reduced and therefore, there is no effective breaking system happening in the whole passenger car. So, valve should close once the breaking force has been released up to a required value. The other failure mode can be microcomputer and associated electronic fail; they do not give any output.

So, let us say these are may possible failure modes for the specific example. So, we have to draw an FMEA work sheet which would include risk priority numbers. We will talk about the slightly later let us try to write down the FMEA work sheet in a qualitative mode without giving any risk priority numbers and identifying the sequence of failure. We will first talk about the qualitative analysis part; let say we are talking about FMEA anti skid breaking system.

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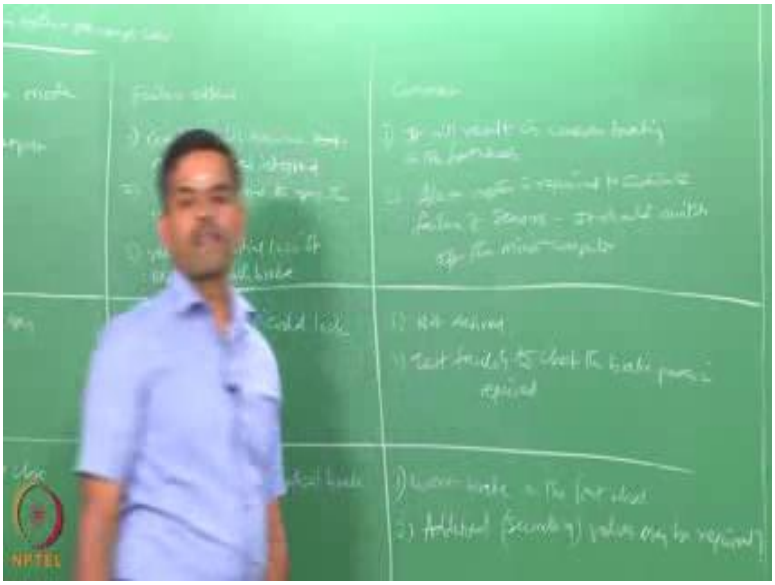

For the passenger car which are very common phenomena in the most of the automobiles now. So, we have the component, as we have identified the component can be front wheel sensors s 1 and s 2. There can be a failure mode as discussed earlier like this the sensors can fail to give output, no output that can be a failure mode of the sensors.

The failure effect which can be a consequence arising from no output from the sensor can be computer will assume. That one wheel has stopped, that can be a possibility because there is no output from the sensor therefore, sends a signal to open the relief valve. So, the result will be results in partial loss of the front wheel brake that is the consequence. So, comment recommendation observation can be it will result in uneven breaking on the front wheels.

So, what should be the advice the advice, could be and alarm system is required to indicate failure of sensors and it should switch off the computer. On the other hand the vehicle should now get shifted to the manual mode. So, that can be one of the analyses for a component where sensors s 1 and s 2 on the front wheel fail to operate. Now the second could be the front wheel valves component could be v 1 and v 2 there are 2 issues here, on demand the valve does not open fails to open on demand the valve does not close. So, both are possible. When the valve does not open one front wheel could lock on

heavy breaking, because depending upon whether v 1 is not opening or v 2 is not opening, corresponding wheel could lock on heavy breaking not desired it has not desired one.

So, the recommendation could be test facility to check the brake power is required. One has to examine this independently if the valve fails to close, it will result in partial loss of the front brake or front wheel brake that is the failure effect or the consequence it will result in uneven breaking, on the front wheels. So, the recommendation could be, additional secondary valves may be required and that is only suggestion. The next mode of failure could be, I will rub this here and write it here itself rear sensor rear wheel sensor s 3.

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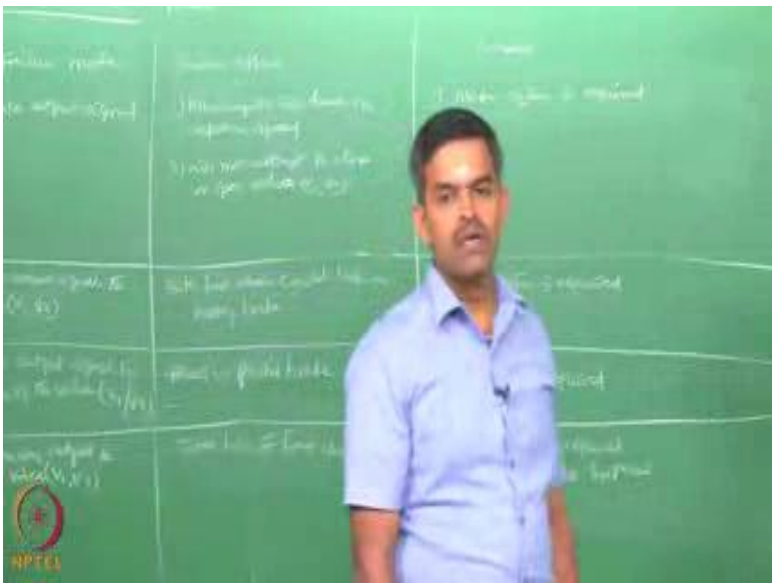

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The failure mode could be no output signal from the sensor. Failure effect could be microcomputer will have no reference speed. No reference speed, therefore, it will not attempt to close or open the valve v 1 and v 2.

So, in such case the recommendation is alarm system is required. So, the next could be microcomputer that is the component. There are many possibilities are here. No output signals, no output signals to the valves v 1 and v 2 because microcomputer is the one which is going to fail now. So, both front wheels could lock on heavy breaking. Action could be alarm system is required. The other failure mode could be, no output signal to one of the valves either v 1 or v 2. Either one there is no supply there is no signal to valves either one of them, result in partial braking alarm system required.

The third failure mode could be spurious output to both the front valves. I mean output is not desired, but output is supplied it is not required, but it is supplied with the computer. Total loss of front wheel breaking alarm system is required. Computer should be switched off or computer control should be by passed it should go the manual mode. So, one can easily analyze various issues related to the functional aspect or inter relationship between the components, which could have a cascading effect ultimately on the overall

system failure which can be done, using an FMEA analysis, which is one of the powerful tools to do qualitative and quantitative analysis both for electromechanical systems.

So, therefore, FMEA is a systematic tool.

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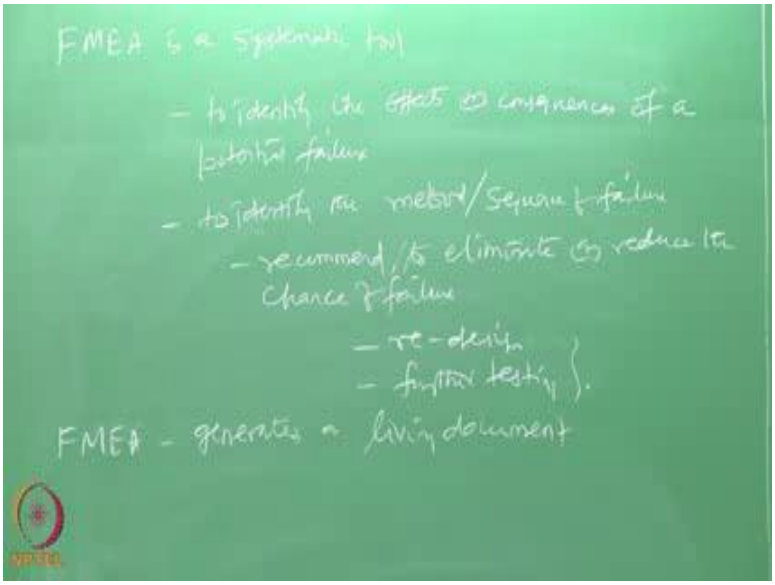

Systematic tool, to identify the effects or let say consequences of a potential failure; it can also identify the method and sequence of failure; thereby it can recommend or recommend to eliminate or reduce the chance of failure. It can advocate re design, it can advocate further testing etcetera. Therefore; one can say that FMEA generates living document, which is useful to anticipate the failure and then prevent it from the occurrence of it. Now the question comes when to use FMEA when to use.

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FMEA essentially it is very effective when used in the design stage. At least it should be used before the final design is released.

So, FMEA is one of the mandatory studies which is to be conducted for assessing the performance of the electromechanical systems. Now what is an objective of FMEA, the primary objective is on failure prevention. It is not on detection. So, it is not the post accidents scenario. It is not hazard identification. It is much more than that it is very effective because it works towards failure prevention itself.

Whereas hazard analysis tries to find out what are the possibilities of occurrence of failure. So, it is detecting the failure. Then you have got to avoid that kind of failure. Whereas, in FMEA study it directly addresses the critical factors which should be corrected, which should be modified so that the failure is prevented at the design stage itself. Therefore, friends FMEA is considered to be one of the most effective tools to assess the performance of electromechanical systems. Therefore, FMEA is actually a standard process, followed to assess the performance of electromechanical systems at the product stage itself.

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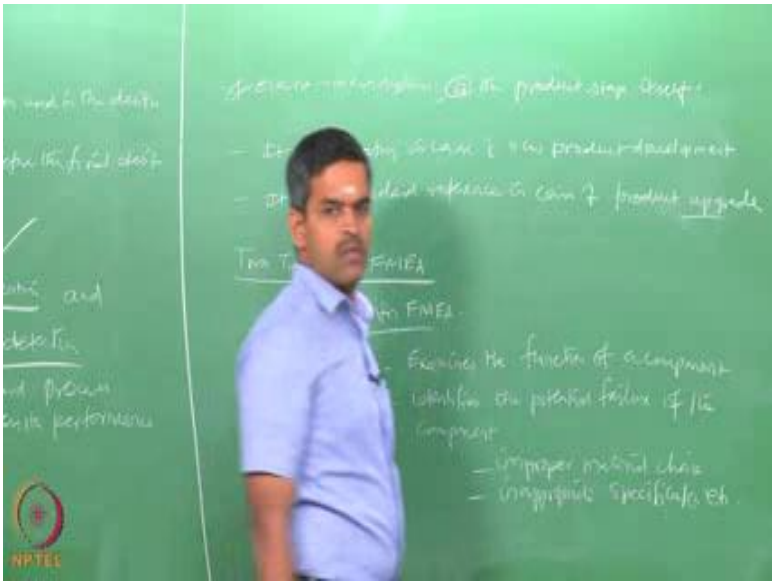

So, it is mandatory in case of new products development. It is a standard reference in case of product gradation. So, in both cases FMEA studies are refereed as a standard document as you see in the black board. Now there are two types of FMEA, one is what we call as design FMEA. Design FMEA actually examines the function of a component present in a system sub system or a main system. It identifies the potential failure of the component in terms of improper material choice, in appropriate specification etcetera. So, therefore, it is a component level analysis. It is also called as micro level analysis.

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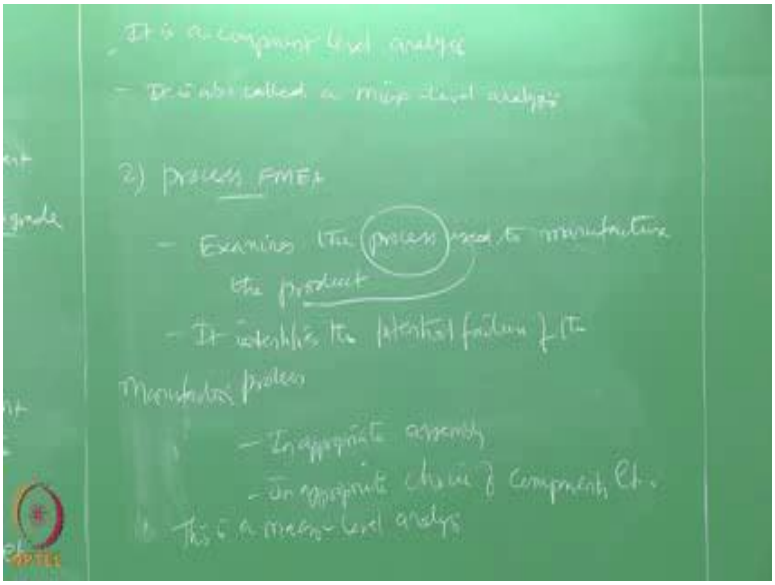

The second FMEA could happen to the process, which examines the process, used to make the product used to manufacture the product. It identifies the potential failure of the process. I should say manufacturing process, by inappropriate assembly, inappropriate choice of components etcetera. Now these are micro level analysis. Because it analyzes the process then comes back to the component, whereas design FMEA starts from the component and goes to the product. As we saw in hazard studies similarly FMEA also has got certain key words.

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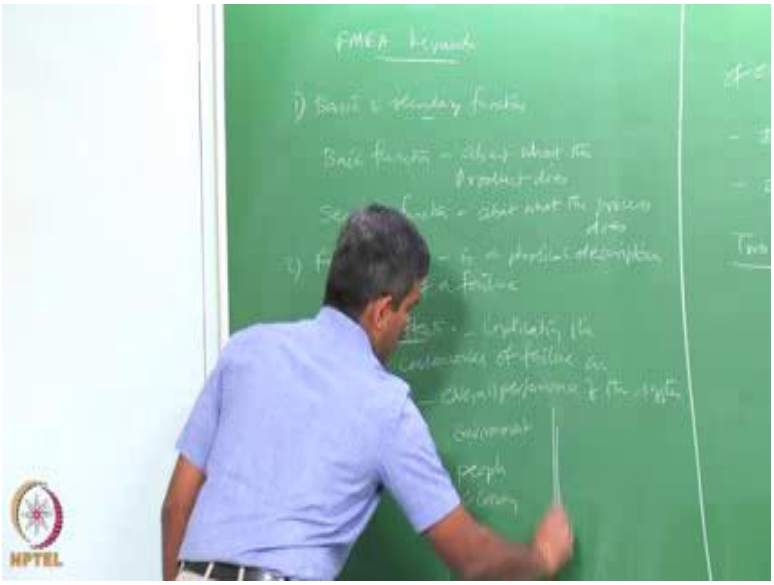

Let us say, basic and secondary functions is one of the keyword commonly used in FMEA study. Basic function describes about what the product does. Secondary function describes about what the process does. The second definition which is required in a FMEA keyword is the failure mode. Failure mode is the physical description of the failure. Third keyword could be failure effects. This is indicating the consequence of failure on overall performance of the system, on environment, on people and of course, on economy also. So, this covers almost all the issues as refereed by risk analysis.

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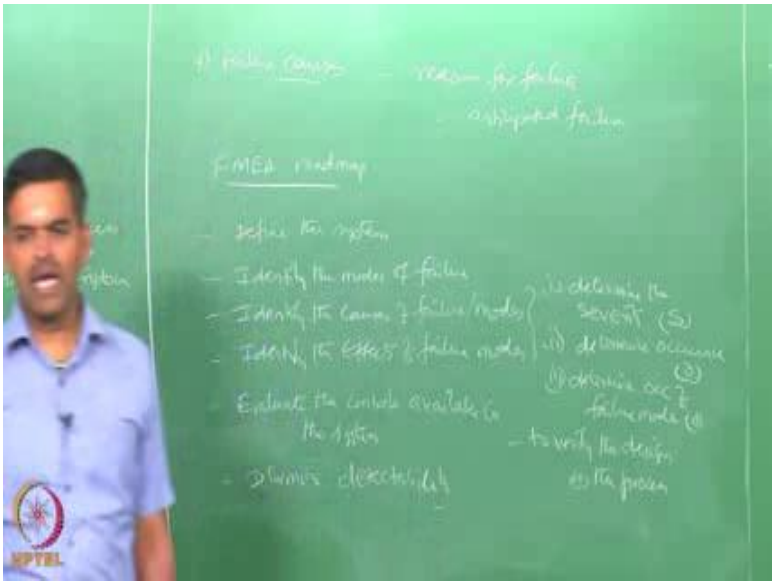

Failure causes this refers to the reasons for failure, in fact, to be very precise the reasons for anticipated failure. Please understand very clearly FMEA is not a post diagnosis of an accident or an incident it is a pre evaluation of a product at the design stage itself. So, all failures are anticipated, if the valve does not open, if the sensor does not transfer output, if the microcomputer fails all these are anticipated failure.

So, anticipated failure identifying the reasons for those failures, that is what the failure cause. Let us try to ask a simple question to ourselves what is an FMEA road map. What does it actually do? In what sequence the work is carried out. If we look at the algorithm or the steps involved in the whole FMEA analysis as we understand from the example of a car anti skid braking system - First is we define the system, subsequently we identified the modes of failure. After identifying the modes of failure, we identify the causes of failure and failure modes. Subsequently we also identify the effects of failure modes in this case we determine two things, one we determine the severity, we also determine the occurrence. Once we did this we move further to identify the cause of failure modes, and we determined the occurrence of failure modes, as well as once we did this we evaluate the current controls available.

This is useful to verify the design or the process what are may be the type of FMEA using design FMEA or process FMEA. Finally, we are interested in detecting or determine the detectability. Is the failure noticeable, then we really see, I can give you a very simple straight forward example for you to understand, if you consider one of the wheels of a car as an important component, which can fail while running, the detectability of the failure of the wheel can be easily seen from a deflated tyre, the tyre is puncture. So, if the failure mode detectable easily can you physically see it can you physically feel it is it visible to the person who is operating the system. So, that is what detect ability is the higher the detectability, the lesser the risk involved because you can always stop the machine etcetera.

For example you are moving an escalator, the escalator buttons are available with top and bottom mode of the operation. If the escalator is stuck up not able to move is easily visibly seen. So, one can always detect that it is not working or you can switch on or off manually escalator. So, the escalator motion can control physically by a manual mode of operation, instead of automatic mode of operation. So, we would also like to know, those failure modes identified by the designer, or they detectable is a any mechanism any provision available in the design, which explicitly shows that the failure mode is detectable or one of the component as failed, which can be seen very clearly in a detectable mode, once we do this we determined. So, we call this as d, we determined risk priority number I will come to this argument slightly later.

Once we know the risk priority number then recommend actions, to correct the consequences or to improve the design. So, that is going to be the FMEA road map which is generally applied to any system, so that qualitative and quantitative aspects of risk analysis are hazard identification are covered in one shot, using this which is very powerful and very common tool. In fact, a mandatory tool for all electromechanical systems in the product development or in product improvement. Friends I hope you have understood this lecture, with an illustrated example of an anti skid braking system on a passenger car.

FMEA is a very simple study, which can be reported. We have seen in this lecture qualitatively how to write an FMEA report now we are. So, far not discussed how to get

risk priority number, which will discuss in the next lecture, by taking another example or the same example we will see how RPN can be computed and therefore, how one can prioritize the risk and based on the risk prioritize how one can suggest the recommended actions.

In fact, I would request to all the viewers to apply these kind of study for any electrical or mechanical system available around you. Look at the working mode of the particular mechanical system take the bicycle for the example; take a motor cycle start applying the study for known products first. Then if you are a petrochemical and offshore engineer start looking at the mechanical working mode of a BOP, which is a blowout preventer can. Try to identify the components of BOP and do an FMEA analysis and see amongst the components present in BOP, or a drilling stack as a hole, which is the most vital and critical component. This will give you a very good in sight of understanding the whole process, which would lead to an accident. Once you are understanding about the processes clear, I am sure you are contributing towards the safety assurance to the maximum level.

Thank you very much.