

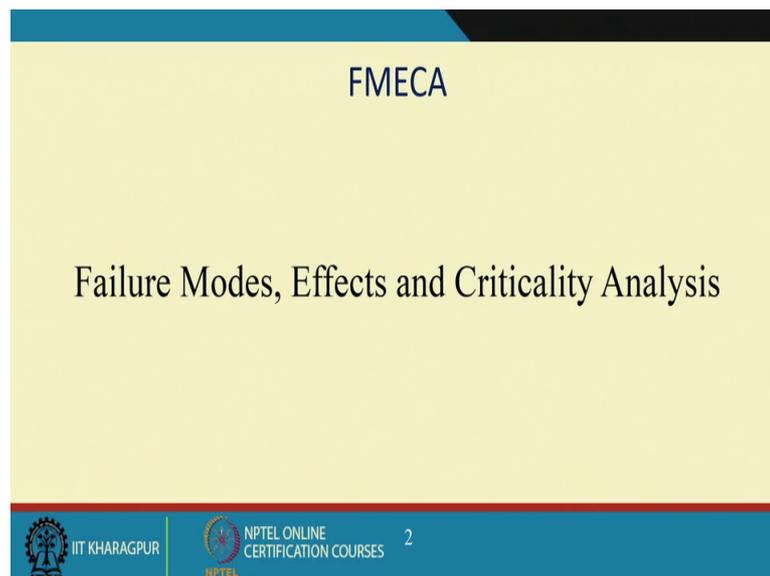
Machinery Fault Diagnosis and Signal Processing
Prof. A. R. Mohanty
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 03
FMECA

This lecture is on FMECA which stands for failure modes effects and criticality analysis. As you know by now we have studied about the three techniques of maintenance, the first being periodic maintenance or the preventive maintenance, second one being the predictive maintenance or what we know as condition based maintenance, and the third one is reactive maintenance or breakdown maintenance.

Now, as you had seen in the last class, we had discussed on an economic analysis that in the long run it is this predictive or condition based maintenance which is economical. But the question is when you have a large plant like a steel plant, like a cement plant, like a shipyard, which equipment needs to be given what kind of priority and maintenance, this is a question everybody would be wondering. So, this FMECA is going to help us identify such critical equipment, which requires more maintenance attention and then we will see how is a mechanism is actually done.

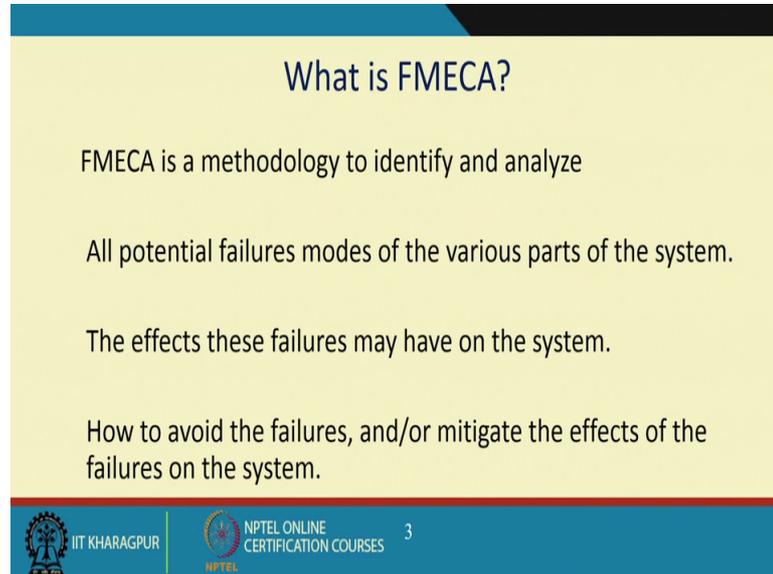
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So, FMECA as you say failure modes effect and criticality analysis.

So, FMECA is the methodology to identify analyze all potential failure modes of the various parts of the system.

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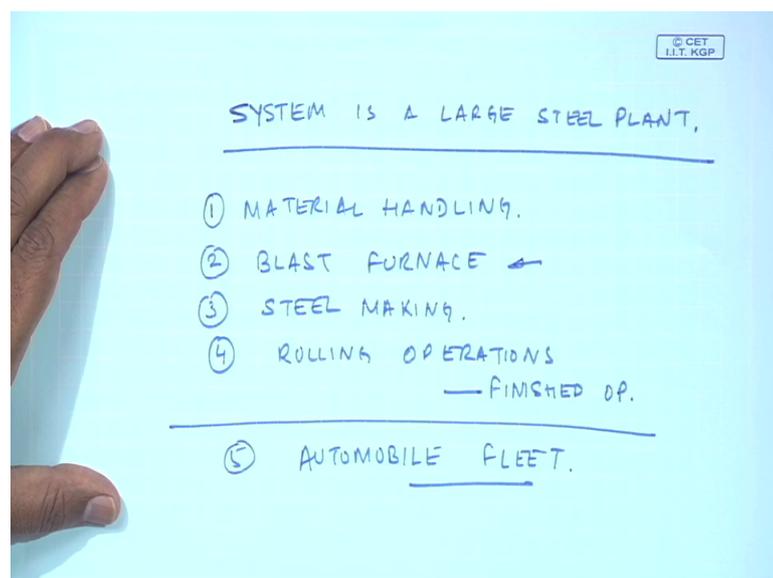
What is FMECA?

- FMECA is a methodology to identify and analyze
- All potential failures modes of the various parts of the system.
- The effects these failures may have on the system.
- How to avoid the failures, and/or mitigate the effects of the failures on the system.

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And the effects these failures may have on the system, and how to avoid the failures and mitigate the effects of the failures on the system. Now in our case for example, a system is a large steel plant. In a steel plant there are many operations broadly if I could classify them.

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SYSTEM IS A LARGE STEEL PLANT,

- ① MATERIAL HANDLING.
- ② BLAST FURNACE ←
- ③ STEEL MAKING.
- ④ ROLLING OPERATIONS
— FINISHED OP.

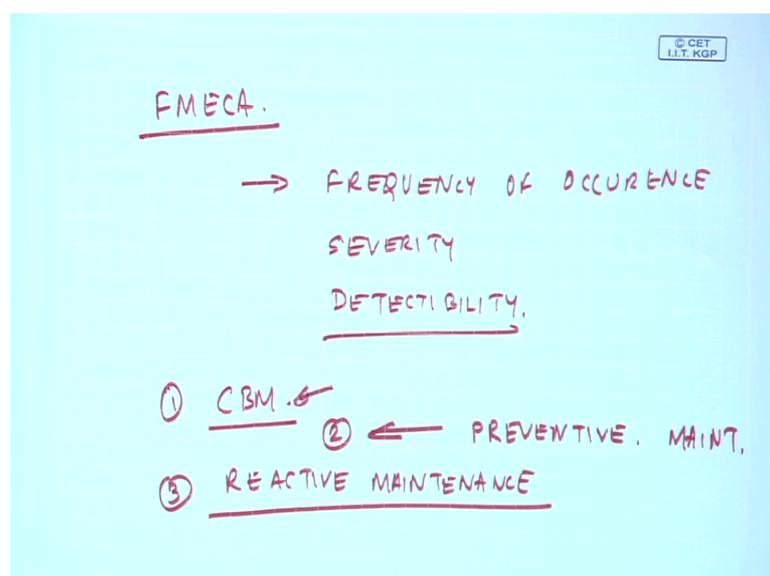
⑤ AUTOMOBILE FLEET.

One is material handling, the raw material handling which bring in the ores etcetera, and then feed to the blast furnace and then we have the steel making performances steelmaking operations, then we have the maybe the rolling operations ore, where we produce the finished parts. This is another could be different other operations also hot rolling cold rolling etcetera

Now, question is in a steel plant each one of these items which I have listed them are very critical. Be it the material handling because we got the materials if the blast furnace is not going to be feed, without the blast furnace I will not have iron to make steel and without the steal; obviously, I cannot have the end product. Now all of them are critical, but in the same steel plant, suppose I have an; for example, we have an automobile fleet. Now should have be giving more care to the automobile fleet instead of the blast furnace you have which you wondering. So obviously, it is the blast furnace which needs to be given more maintenance attention as opposed to an automobile fleet, or as giving an example, the canteen water cooler; water cooler in the cafeteria.

So, we see that there is an index of criticality in all this equipment, and this criticality is studied through a method, which is being used by industrial engineers and which is known as this FMECA.

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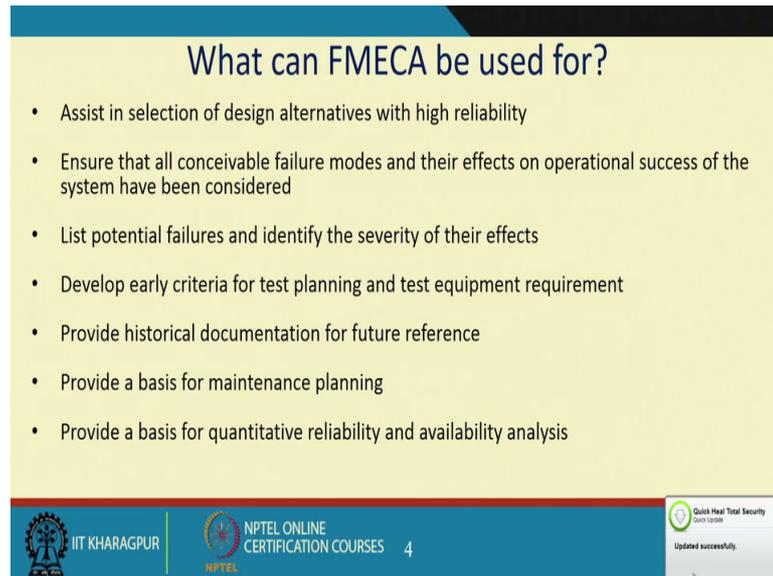


So, FMECA is actually done it will almost all aspects of life, FMECA somebody does when preparing from an exam I mean which course it needs to give him more attention

as opposed to know maybe a person is strong in a subject. So, he need not give that much attention to that subject to pass the exams. So, if he is weak in a subject he needs to more effort in that weak subject.

So, we all in some way or the other practice FMECA in our daily life.

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What can FMECA be used for?

- Assist in selection of design alternatives with high reliability
- Ensure that all conceivable failure modes and their effects on operational success of the system have been considered
- List potential failures and identify the severity of their effects
- Develop early criteria for test planning and test equipment requirement
- Provide historical documentation for future reference
- Provide a basis for maintenance planning
- Provide a basis for quantitative reliability and availability analysis

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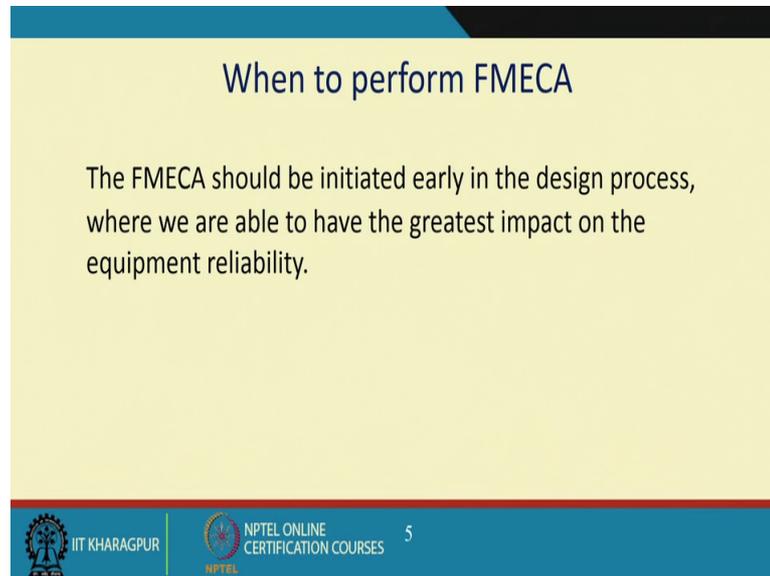
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Data Update
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So, FMECA can be used to decide and design ultimate the alternatives of high reliability, ensure that all conceivable failure modes and their effects on operational success of the system have been considered, list of potential failures and identify the severity of their efforts and so on. So, one of course, you know what is the frequency of occurrence of the defect, severity and deductibility. It may so happen in the steel plant, if your blast furnace is down a steel plant is shut down, but maybe if your material handling is down you may be having alternate roots of material handling or material handling can be easily some arrangements could be done to have a backup material handling system, which may not be true if your blast furnace all together fail. So, we all get a feel of what this criticality is, and the golden rule here is our equipment which is critical requires more attention in terms of maintenance.

Now this maintenance could be; because of no maintenance could be CBM, and if I do not do any maintenance which is known as the reactive maintenance, and in between we have the preventive maintenance. So, there is a grading of this maintenance in terms of CBM preventive maintenance and reactive maintenance. So, if I equipment is very

critical, I need to always monitor it. So, I will that will be a good (Refer Time: 07:20) for CBM and so on.

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When to perform FMECA

The FMECA should be initiated early in the design process, where we are able to have the greatest impact on the equipment reliability.

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So, how do you perform or when do we perform FMECA. So, FMECA should be initiated early in the design process, where we are able to have the greatest impact on the equipment elaborate that I have, I have a robust design and that my equipment is highly reliable I would then you know give least importance in its maintenance and so on. So, in all process be it designed, be it manufacturing, be it maintenance everywhere in an industry we can have FMECA.

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Types of FMECA

- Design FMECA is carried out to eliminate failures during equipment design, taking into account all type of failures during the whole life-span of the equipment
- Process FMECA is focused on problems stemming from how the equipment is manufactured, maintained or operated
- System FMECA looks for potential problems and bottlenecks in larger processes, such as entire production lines

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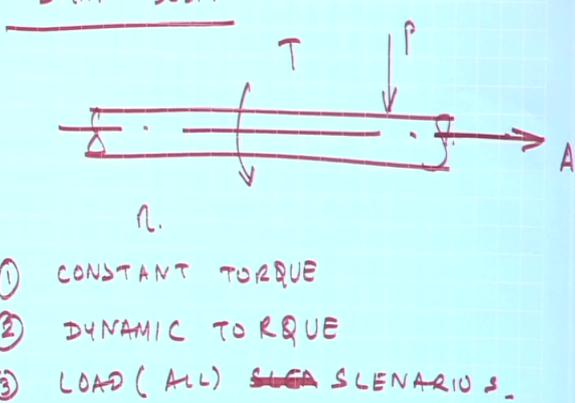
So, in a design FMECA, it is carried out to eliminate failure modes during equipment design taking into all types of failure during the whole lifespan of the equipment.

Now, somebody is designing a shaft, well principles of machine design somebody may say well I have designed the shaft because it is used to it is allowed to take a certain torque, and then in a what is the developed (Refer Time: 08:35) stressed.

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SHAFT DESIGN



The diagram shows a horizontal shaft with a double-headed arrow labeled 'T' indicating torque. A vertical arrow labeled 'P' points downwards from the shaft, representing a load. The shaft is supported by bearings at both ends. Below the shaft, the Greek letter n is written. Below the diagram, there is a list of three scenarios:

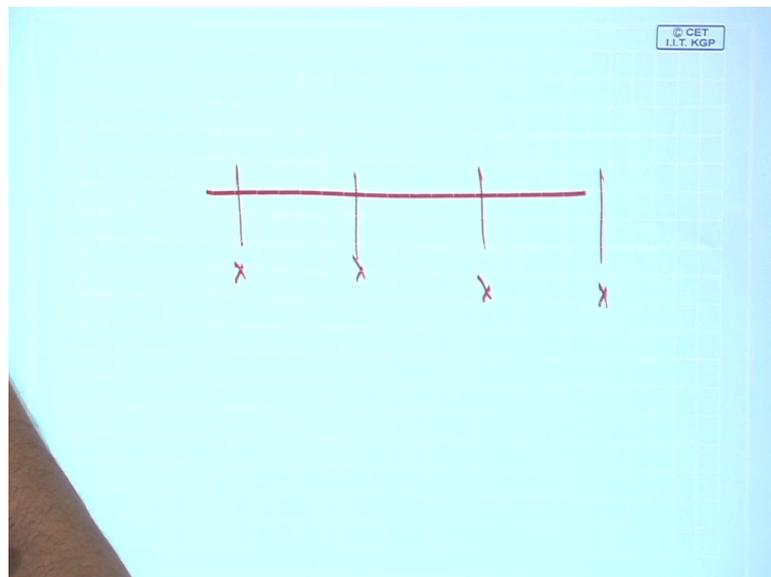
- ① CONSTANT TORQUE
- ② DYNAMIC TORQUE
- ③ LOAD (ALL) ~~SCENARIOS~~ SCENARIOS

But this could be one design, just looking at the constant torque on the shaft. Another scenario could be there is a lot of dynamic torque on the shaft as well, on top of it there

could be some flexural loads, there could be some axial loads. So, all sorts of loading scenarios, what happens? Somebody has done designed through a constant torque or design only considering dynamic torque or dynamic design considering all sorts of loads and bending load, an actual load or torsional dynamic load. So, this means if I have chosen the last one I have a robust design.

So, in a design FMECA people take into account all sorts of considerations of failure while designing this equipment, and they can decide on whether your design is more robust and so on. Similarly in the process in a process in a manufacturing process, there are many bottlenecks in the manufacturing assembly line.

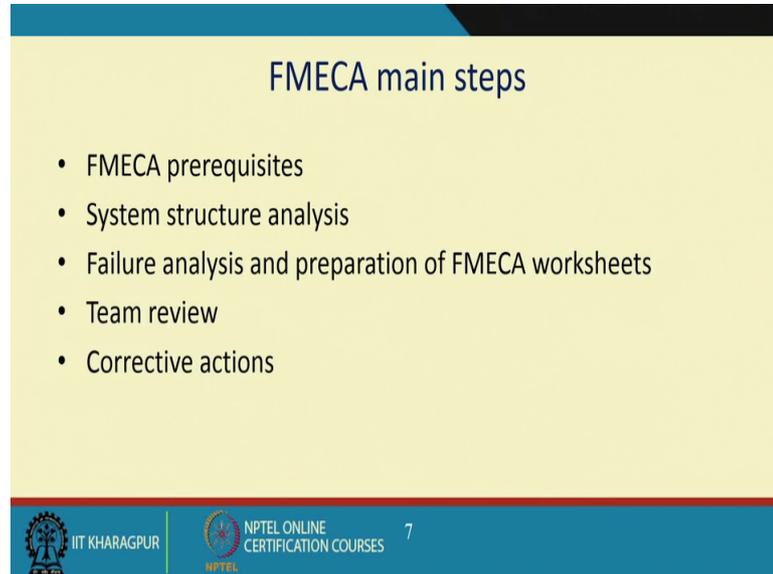
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For example, have all been considered and that we can do through a FMECA custody. For example, in an assembly line, there is you know assembly line of an automobile there are many critical points, you know have the engine put in and then we have the body shell put in, then they we have wiring harness put in, then the suspension system put in. So, if one is not done properly it is going to affect the end product. So, a manufacturing FMECA is also done to find out the robust processes and so, industrial engineers plan designers you know and so on decide on the critical component and then they ensure that enough care is taken to ensure that the system is robust and the process is accurate

So, system FMECA looks for potential problems and bottlenecks and large processes such as entire production lines.

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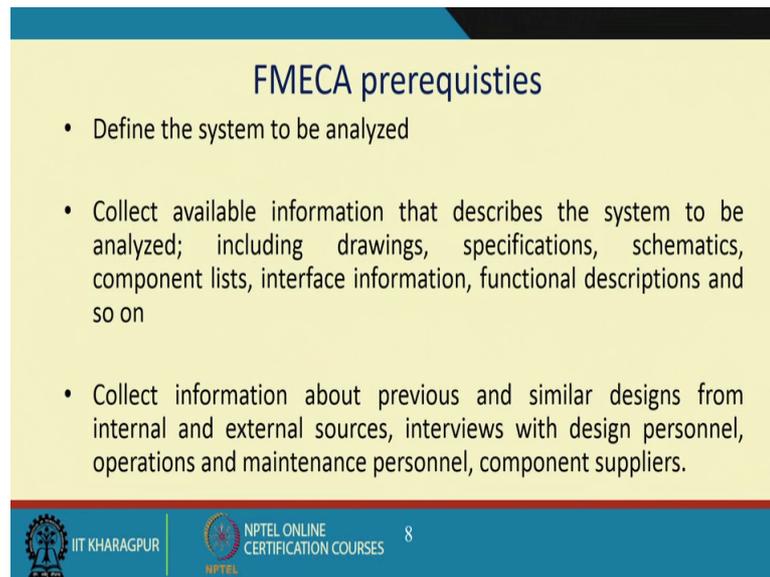
FMECA main steps

- FMECA prerequisites
- System structure analysis
- Failure analysis and preparation of FMECA worksheets
- Team review
- Corrective actions

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So, what I mean to say is FMECA is almost done everywhere. So, what are the main steps of being FMECA well? One needs to break down a system into its important structures like I gave you the example of the steel plant, wherein we are the material handling the blast furnace the steel melting processes and the rolling mill. So, these are all the individual systems of a steel plant, we need to find out if a blast furnace is failing what are the critical components inside the blast furnaces. So, blast furnace could be a sub system itself and then we can have team, you know team suggesting what are the critical components and then what kind of corrective actions need to be taken so that this is done.

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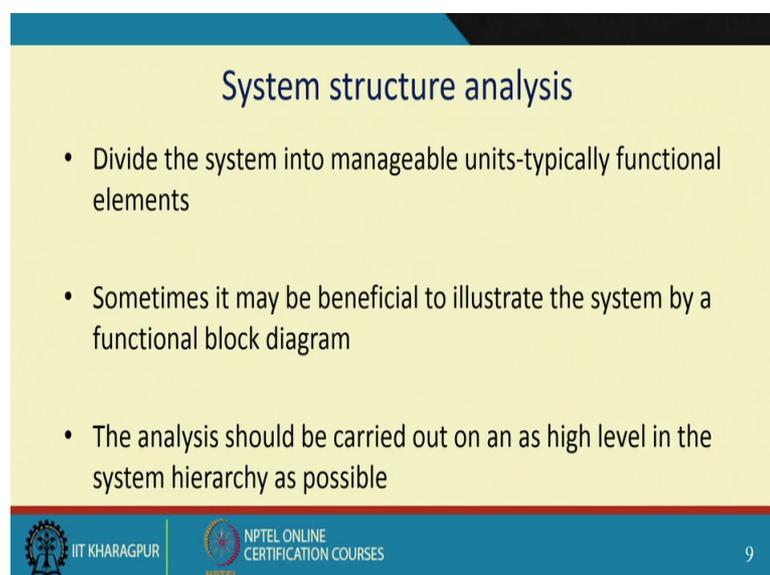
FMECA prerequisites

- Define the system to be analyzed
- Collect available information that describes the system to be analyzed; including drawings, specifications, schematics, component lists, interface information, functional descriptions and so on
- Collect information about previous and similar designs from internal and external sources, interviews with design personnel, operations and maintenance personnel, component suppliers.

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So, we have to clearly define the system to be analyzed, and collect available information that describes the system to be analyzed including drawing specificity etcetera. Collect information about previous and similar designs from internal external sources, interviews with design personnel and so on operational and maintenance personnel. Because sometimes our designer will have done a FMECA, but the ground reality some feedback thing that needs to be taken from the operators or the personnel in the shop floor, regarding the equipments reliability how poor or how good it is doing. So, this is actually necessary.

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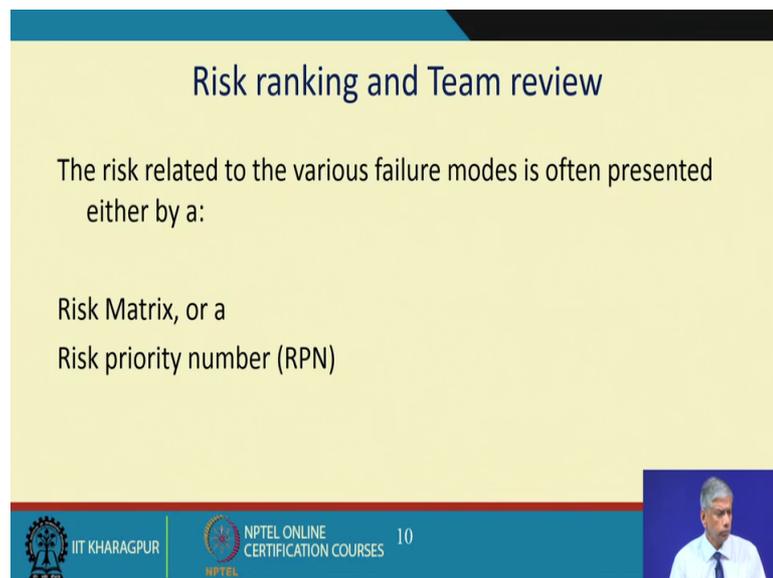
System structure analysis

- Divide the system into manageable units-typically functional elements
- Sometimes it may be beneficial to illustrate the system by a functional block diagram
- The analysis should be carried out on an as high level in the system hierarchy as possible

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And divided the system into manageable units typically functional elements. Like example of steel plan, sometimes it may be beneficial to illustrate that by a block diagram and analysis should be carry out as an high level in system hierarchy as possible.

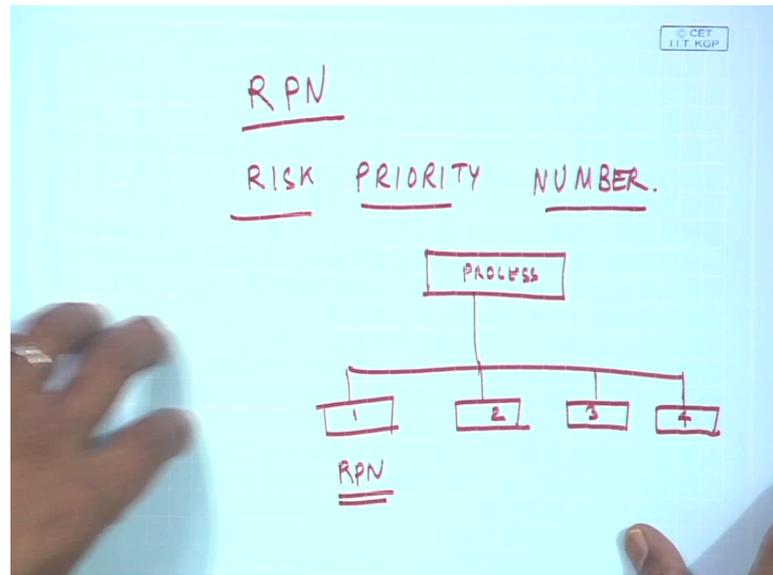
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The slide is titled "Risk ranking and Team review". The main text reads: "The risk related to the various failure modes is often presented either by a: Risk Matrix, or a Risk priority number (RPN)". At the bottom left, there are logos for IIT Kharagpur and NPTEL. At the bottom right, there is a small video inset showing a man in a white shirt and tie. The slide number "10" is visible in the bottom right corner.

Now the most important number of them is known as the risk priority number in FMECA clinical. So, from FMECA we find out what is known as a risk, priority number for any process which constitutes for example, this is my process and then it has many sub processes.

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So, process 1, 2, 3. So, all these give rise to this process, I mean whether it is 1 which is important or 2 which is important 3. So, you have to find out RPN for each one of them and how do you find out RPN is I am tell you next.

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Risk priority number

- O= the rank of the occurrence of the failure mode
- S=the rank of the severity of the failure mode
- D=the rank of the likelihood that the failure will be detected before the system reaches the end-user/customer
- All ranks are given on a scale from 1 to 10. The risk priority number (RPN) is defined as $RPN=O \times S \times D$
- The smaller RPN the better – and – the larger the worse

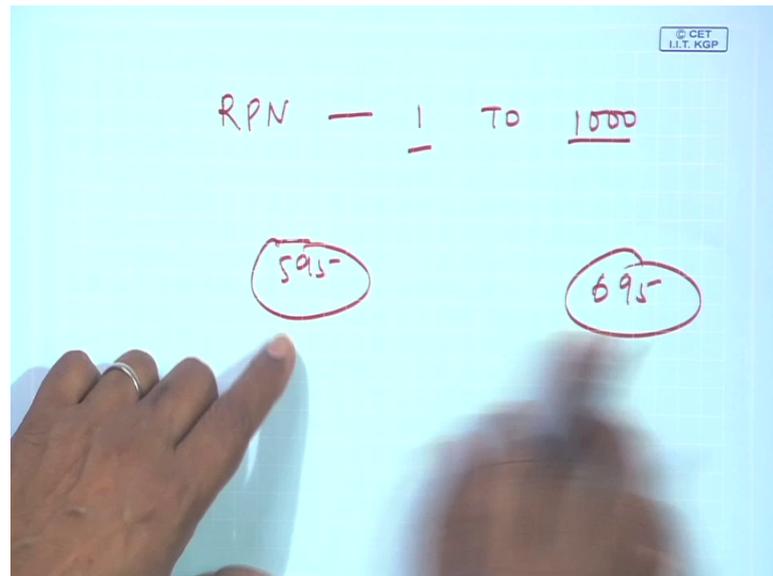
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So, RPN is actually defined by this quantity OSD. O is the rank of the occurrence of the failure mode when we a talk about failure FMECA that means, how or what is the frequency of occurrence of this failure mode, S is the rank of the severity the filament means if of fail failure has occurred, how is it going to affect the process and if you a

manufacturer rank that the likelihood that the failure will be detected before the system reaches the end user or the customer.

So, all each one of these is given a rank you know from 1 to 10. So, the highest value of RPN will be 10 times 10 that is 1000 and the smallest one is the one.

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So, RPN could vary from all the way from 1 to 1000, but there is no basis of whether you know there is no units to this number and there is no basis that it says that you know one RPN has given you 595 in one study, the same machine in another study has given you 395. There is no comparison and we should not compare and because FMECA is done by a team of people with their personal opinion into account taking into account the machines criticality, occurrence of the defect and the likelihood that the fillable reach the customer. So, there is no clear meaning.

I will explain this FMECA through an example, may be this pen I will talk about the jotter pen manufacturer.

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JOTTER PEN MANUFACTURER.

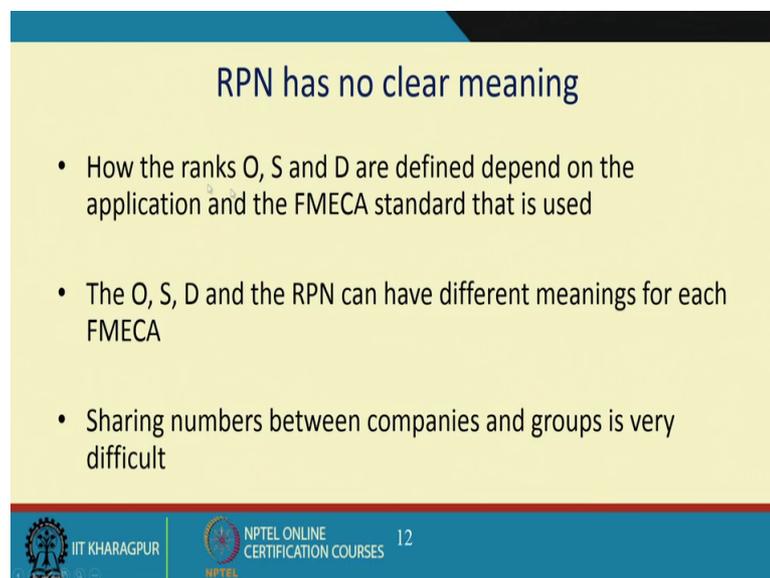
	O	S	D	RPN
① BODY OF THE PEN	2	2	2	8
② CAP OF THE PEN	4	1	2	8
→ ③ REFILL OF THE PEN	5	9	8	360
④ ASSEMBLY OF ALL COMPONENTS	2	5	3	30

So, in a jotter pen manufacturer, for the sake of discussions I will take two jotter pen as one is the body of the pen. Body of the pen may be cap of the pen and then maybe the refill of the pen, and during the manufacturing assembly of all components. See if I give values of O S D and then of course, calculate RPN (Refer Time: 16:57) product of these. So, what is the frequency of occurrence that there is a defect in the body of the pen maybe from a value from 1 to 10, I will give something like 2 cap of the pen yeah maybe this clip of the cap would break maybe 4, refill of the maybe the refill could have really could have dried etcetera and give a 5 number assembly looks I will give low number.

Then comes the severity of the defect; see if the body of the pen develops a crack, but the job function that the pen is still going to write is fine. So, I will give it low number, cap of the; if it breaks my pen is still going right. Refill of the pen has failed this is a severe I mean if the refill has failed, the pen would fail the assembly of the after all components of the refill if not put properly then pen I would number 5. Now demonstrate is the rank of the likelihood that the failure will be detected before the system, which is the end customer either or customer. This is I am looking for a pen is just point of view, the body of the pen would be very easily detected because it is from the outside. So, I will give it low value cap also you can refill of the pen, which is inside I cannot see it as a defect, I will give it a high value. Assembly of the all components we you can give it a low value.

So, if you see from multiply this becomes 8, this becomes 8, 49 and this is 30. So, if you see for a pen manufacturer buy this simple example, it stands out that the machine which is manufacturing the refill needs to be given more critical care and that is what I wanted to demonstrate here the importance of FMECA or RPN in terms of finding out the critical component in a pen. So, RPN has no clear meaning for example, these numbers RPN has no meaning 8, 8 360 it is just a rank and; obviously, the same exercise if I gave to the entire class to do everybody may have come up with different numbers, but the conclusion would perhaps be the same that it is yes the refill of the pen, which is the most critical component in this pen manufacturer.

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The slide has a yellow background with a blue header and footer. The title 'RPN has no clear meaning' is centered at the top. Below it are three bullet points. The footer contains logos for IIT Kharagpur and NPTEL, along with the text 'NPTEL ONLINE CERTIFICATION COURSES' and the number '12'.

RPN has no clear meaning

- How the ranks O, S and D are defined depend on the application and the FMECA standard that is used
- The O, S, D and the RPN can have different meanings for each FMECA
- Sharing numbers between companies and groups is very difficult

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So, the ranks O, S and D are defined depend on the application and FMECA standard that is used, and RPN can have different meanings for each FMECA and sharing numbers between companies and groups is very very difficult.

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Review objectives

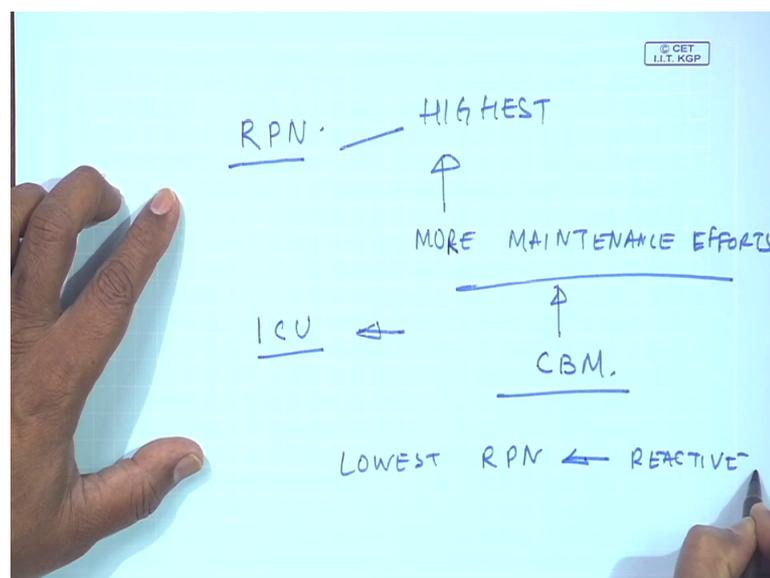
The review team studies the FMECA worksheets and the risk matrices and/or the risk priority number. The main objectives are

1. To decide whether or not the system is acceptable
2. To identify feasible improvements of the system to reduce the risk. This may be achieved by
 - (a) Reducing the likelihood of occurrence of failure
 - (b) Reduce the effects of failure
 - (c) Increasing the likelihood that the failure is detected before the system reaches the end-user

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So, you could do FMECA for any operation for that matter. So, how do we do the review of the FMECA? So, FMECA could be decided by making worksheets, wherein in every worksheet we calculate the RPN whether the system is acceptable or not and to identify improvements to the system to reduce the risk, because what am I doing? Once I know RPN.

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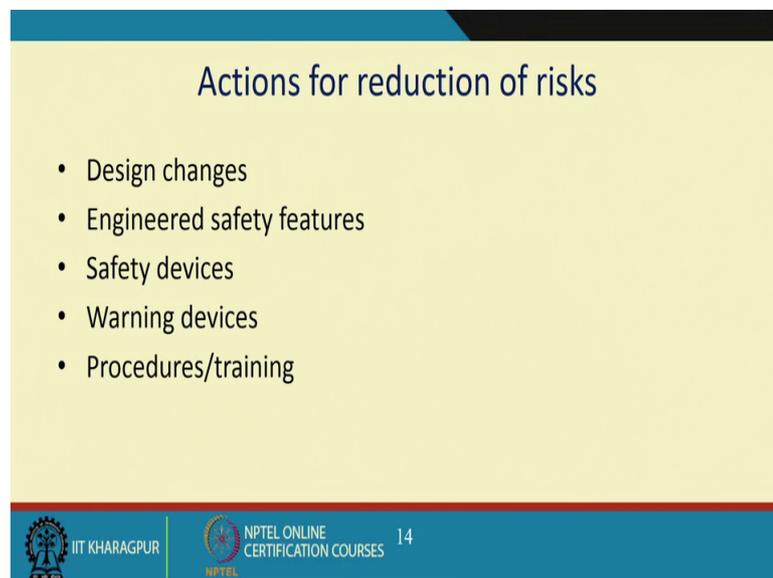


If RPN is highest then maintenance efforts given to it, this is very intuitively when you say a patient is in ICU intensive care unit. So, the doctors or the nurse give more care to

that patient because the patient is critical. So, maybe there is a risk true is on our life. So, more care needs to be given, rather than you know somebody going in an in a general outdoor OPd ok

So, the same principle FMECA is used to find it out critical machines and then of course, if I give more maintenance efforts, perhaps you know maybe online monitoring through CBM and one which are the lowest risk perhaps I could go for reactive maintenance. So, right in the implementation of a maintenance planning program in an industry people need to do FMECA so that they know where to put in what kind of effort for their maintenance.

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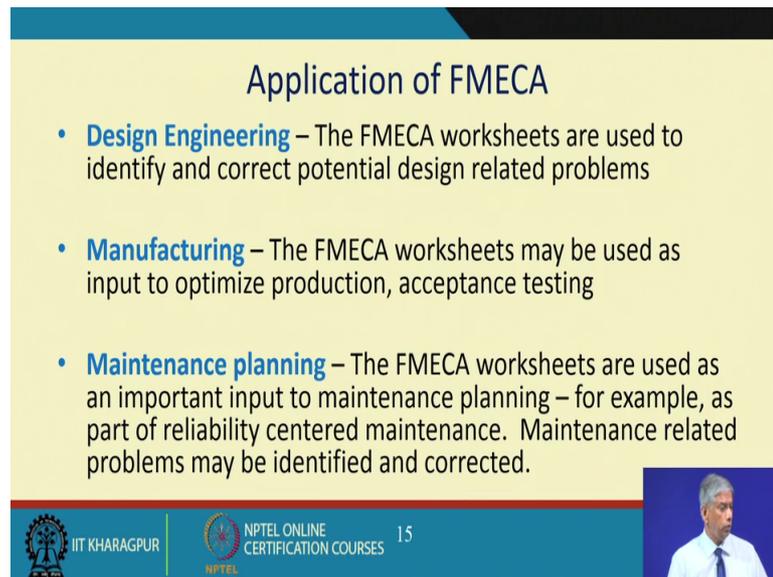
Actions for reduction of risks

- Design changes
- Engineered safety features
- Safety devices
- Warning devices
- Procedures/training

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Well how do you what are the actions taken to reduce this risk maybe do some design changes maybe engineer or have safety features in that, put safety devices, put warning devices and let people have proper procedure and training do that.

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Application of FMECA

- **Design Engineering** – The FMECA worksheets are used to identify and correct potential design related problems
- **Manufacturing** – The FMECA worksheets may be used as input to optimize production, acceptance testing
- **Maintenance planning** – The FMECA worksheets are used as an important input to maintenance planning – for example, as part of reliability centered maintenance. Maintenance related problems may be identified and corrected.

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So, FMECA today is used everywhere and design in manufacturing and production line planning and of course, in maintenance. So, FMECA becomes part of what we today is known as the reliability centered maintenance, through FMECA people can find out which is the least reliable manufacturing methods or which is the least reliable machine and what kind of maintenance needs to be taken and correct it.

So, in an conclusion, this FMECA is helps us understand the critical machines and then we will see what kind of applications of FMECA is done to find out the most critical machines and then what kind of maintenance efforts to be done.

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The slide is titled "Resources" and is set against a light yellow background. It contains a bulleted list of three items. The first item is a book reference by A. R. Mohanty. The second item is a website URL. The third item provides contact information for Prof. A. R. Mohanty, including a phone number and an email address. At the bottom of the slide, there is a blue footer bar containing the logos for IIT Kharagpur and NPTEL Online Certification Courses, along with the page number 16.

Resources

- A. R. Mohanty, "Machinery Condition Monitoring-Principles and Practices" CRC Press, 2014.
- www.iitnoise.com
- Contact Prof. A. R. Mohanty at 94340-16966 or email: amohanty@mech.iitkgp.ernet.in

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The details of FMECA can be found in my book and of course, time to time I would be giving you certain notes at this website, and then you can either contact me for any questions or email me, and more details you will find in my book well defer there is a chapter on FMECA.

Thank you.