Production and Operation Management
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Lecture 55
Maintenance Performance Measures and OEE Calculations

Welcome friends. And in our last session, we started discussions about maintenance management. We discussed that, maintenance is a very important thing and one of the oldest concept in the scientific management is related to maintenance only. The idea was that, if you have a plant which is working continuously without failure, you will be able to produce more and more and then obviously you will be able to sell a huge amount of quantities.

So, initial focus is on maintenance issues but over a period of time, maintenance has gone tremendous change. Earlier concepts of management were more reactive in nature. Whenever some failure took place, we thought of doing some kind of improvement, doing the fixing of the problem and that was known as breakdown maintenance. But people realized that breakdown maintenance is actually a very costly affair because it interrupts your entire production planning.

You will not be able to deliver products on due dates. And therefore, the concept of preventive maintenance came into picture, that we have a schedule of maintenance and based on that schedule of maintenance we are able to give a proper due date of delivery of our products to the customers. Now, there is a continuous discussion that more preventive maintenance will reduce the issues related to break down maintenance.

But in our previous session, we discussed that there is a cost of preventive maintenance, and there is a cost of breakdown maintenance. We want to develop a maintenance plan which can minimize the cost of overall maintenance system and there is an optimum level of preventive maintenance. Moving further, we discussed the concept of maintenance where we know the condition of a particular equipment and based on that condition, we are able to decide the maintenance schedule, that we call as predictive maintenance.

And finally, we discussed the concept of maintenance through which we can take some strategic advantage and that is TPM, Total Productive Maintenance. So, all these different alternatives of maintenance we have already discussed in our previous session. Now, in this particular session, we are going to discuss the performance measures of our maintenance planning. And very, one

very important concept that we are going to discuss that is OEE calculations. OEE stands for, Over All Equipment Effectiveness. So, that is a very important indicator for overall, for the holistic understanding of maintenance issues.

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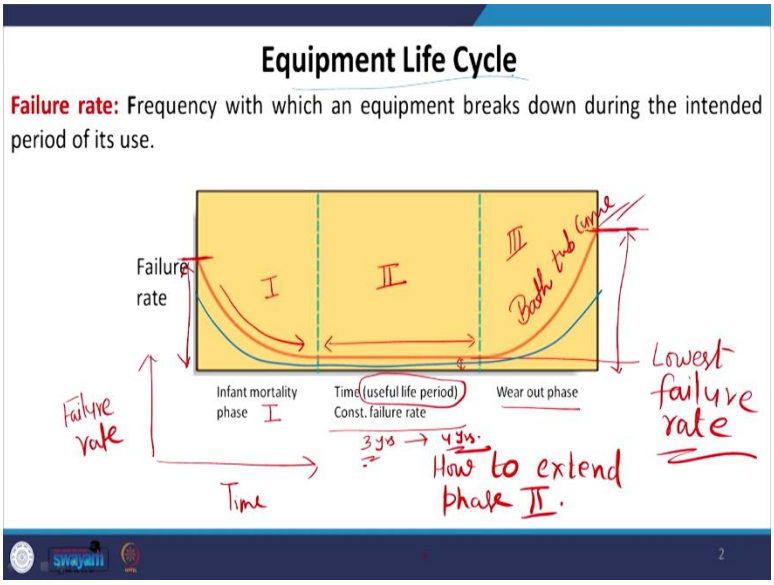

So now, let us start with one very important concept that is the equipment lifecycle. Now, what is this equipment lifecycle, this you can see with the help of this curve. Now, this is known as bathtub curve. Now in this particular diagram, we have 2 axes. Now, the y axis represents the failure rate and x axis represents the time.

Here you see, 3 different phases in this life cycle. The first phase, where the failure rate is very high initially, but after some time, failure rate is decreasing the rate at which product fails. So that failure rate is decreasing after initial few periods. Then in the second phase, where the failure rate remains at a very low level and it is fairly constant kind of failure rate and it is a low level of failure rate.

You can say that this is the most productive period of the product's life, it is the most useful period of the equipment. So here, actually you are able to see that the failure rate is at the lowest level, so you can say that this is lowest failure rate. So, it becomes a very important thing for us to remember that the lowest failure rate of any equipment is in this second phase. And then comes the third phase, where slowly and slowly, the failure rate again starts increasing and it is the phase of wear out.

When the replacement of equipment, replacement of that particular product is required because the product has completed almost its complete life and then it requires replacement. So here, you can say that the first phase is known as infant mortality phase, where after some time the failure rate decreases. It is very similar; it is very similar to our human beings life. When a baby is born at that time initially, the failure rate means the chances of getting sick is very high.

You need to save that child from extreme cold, extreme weathers. And there are possibilities that even with those care, regular failures are possible, regular failures means you may need to visit doctor again and again. So, that is the period of infant phase. After some time when that child grows up may come into the ages of 15 years, 16 years or 18 years plus then probably up to 60 years that is the productive life of the child.

And now that human being and that is the period where that person, that human being is able to take care of all types of weathers without any kind of failure, without getting sick normally. So, that is the second phase. Then after 60 plus, your ability to work again reduces you again become susceptible to various types of sickness and there are different types of problem. Though, in the infant mortality rate, in the phase 1, and in phase 3, failure rates are high but the reason of failure rates may be different.

In phase 1, the reason of failure it is transition period because you are using a new equipment, you are using a new product. So, it might not be able to adjust within the main equipment, within the main product. So, because of those initial challenges (())(8:04) we call it, these failures are possible. In the third phase, because the product has completed its useful life, so lot of wear and tear has taken place and therefore, we require replacement of that.

So, this is a very important type of graph where you know that the useful life is in this second phase. With our suitable maintenance plan, with our maintenance strategies what we continuously like to have that we want to elongate how to extend phase 2. Like in our daily life, we do yoga, we do exercise, we eat healthy food. The purpose is, we need to elongate the period of useful life in that 60 years. Can it be 65 years, can it be 70 years, so we want to continuously work hard, we want to use all the better things in our life, so that we can elongate the period of useful productivity in our lives.

Similarly, with respect to proper maintenance plans, with respect to using the TPM type of concept we can elongate the period of useful life of the product. We can take, this useful life is 3 years, can it be 4 years, can it be 4 years 1 month, so that type of things are possible when we have a suitable plan of maintenance.

So, because bathtub curve is very important and another important thing is that how we can reduce the failure rates in phase 1 and phase 3. Like in this particular case, this is touching this much height, here it is touching this much height, so these are the heights of the failure rate, in the beginning and in the last phase. Can it be possible that our new curve, our new curve starts from here and then it goes like this way, and then it goes like this.

So, that is again possible with the proper maintenance planning that you take minimum failures, because whenever failure is taking place, it is going to incur cost, it is going to disrupt your production schedule. So therefore, it is important that we make a better plan, so that we can actually play with this bathtub curve. So, this is one important thing about the measurement of our maintenance plan.

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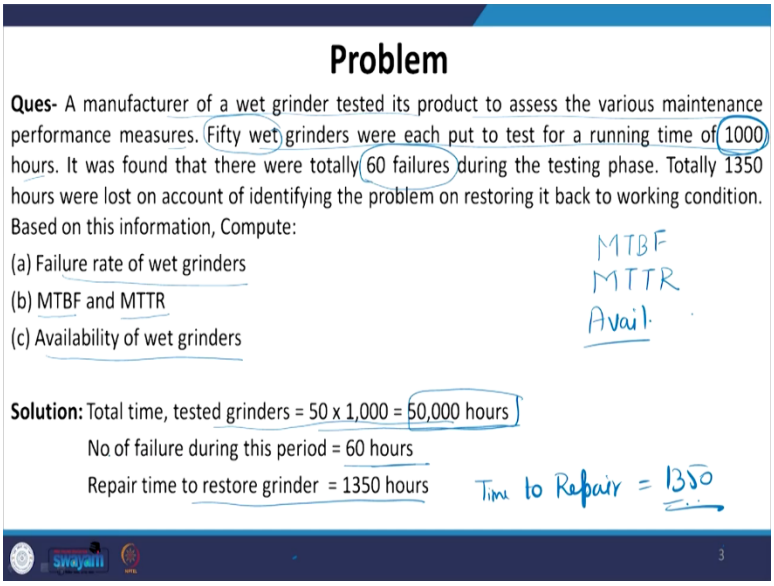

Now in our last session, we discussed the concept of availability, we discussed the concept of MTBF, we discussed the concept of MTTR, and we discussed the concept of availability. Now, based on these 3 concepts, we have a numerical problem. And let us see, how do we solve that. So, some data is given to us.

Now the data reads like that, a manufacturer of a wet grinder tested its product to assess the various maintenance performance measures. 50 wet grinders were each put to test for a running time of 1000 hours. So, total running time is 1000 hours, this is important data. It was found that there were totally 60 failures during the testing phase, totally 1350 hours were lost on account of identifying the problems on restoring it back to working conditions.

So, this is the total data available with us. Now based on that, we will calculate about the failure rate of wet grinders, mean time between failure, mean time to repair, and availability of the wet grinders. So now this calculation says that total time the testing was done because 50 grinders were tested for 1000 hours each, so total testing time is 50000 hours, that is the total time of testing. Now, during this number of failures is 60 hours and repair time to restore grinders, that is time to repair 1350.

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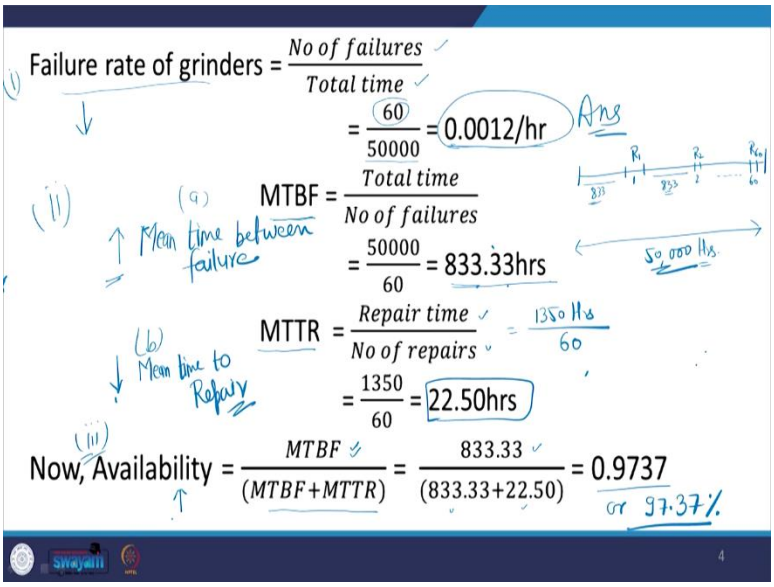

Now based on this, we will do the calculations. Now the failure rate of grinder is number of failures divided by total time. Total 60 failures were identified, 60 divided by total time for which the test was done, 50000 hours. So, the failure rate is 0.0012 failures per hour. This is 0.0012 failures per hour, or you can say that in how many hours 1 failure will take place.

So, it can we read otherwise also, so it is the failure rate. Now mean time between failure, this is mean time between failure. Now mean time between failure is total time divided by number of failures. Now, the concept we have already discussed like this is the total time, that is 50000

hours and total 60 failures are taking place. One failure here, second here, and so on. This is the sixtieth failure. So, these are the 60 failures which took place over this 50000 hours.

So, the mean time between failure is the total time divided by number of failures. So 833, so on an average after 833 hours failure are taking place, on an average after 833 hours failures are taking place. Now this is another metric that is mean time to repair, now mean time to repair is repair time divided by number of repairs. So, this is one repair time, this is another repair time, and this is the sixtieth repair time.

So, since 60 times failures have been detected, so 60 repairs need to be done and total time used in the repair activity is given as 1350 hours and number of repairs is equal to number of failures that is 60. So, 22.50 hours, that is the mean time to repair. Each time whenever a failure is taking place around 22.50 hours are being taken to repair that failure. So now, the availability, the 3 things are asked in this question.

One is the failure rate, that is this answer. The second is the calculation of MTBF and MTTR. And third thing is availability, availability is during which time product is available divided by the total time. So, MTBF divided by MTBF plus MTTR that is 833.33 divided by 833 plus 22, so availability is 0.9737 or it can be written as 97.37 percent. So, product is available, these grinders are available to you 97.37 percent of the time, out of the total time that is the 50000 hours 97.37 percent of the times these grinders are available. So, we got these calculations.

Now as a maintenance engineer, as a maintenance manager, we need to see that we want to reduce the failure rate, how to reduce the failure rate. We want to improve the mean time to, mean time between failure, it should be as high as possible. We want to reduce the mean time to repair, we want to decrease the mean time to repair. It means that, your product has good maintainability whenever it fails it can be quickly fixed, it can be quickly restored, so that is mean time to repair it.

And finally, we want high availability that all through the life, how much percentage of the time the product is available to you, that is the availability. So, that is the calculation of your maintenance management plan. We want low failure rate, we want high MTBF, we want low MTTR, and we want a high availability. So, that is how you can summarize this whole

discussion. Now the alternative maintenance plans, which I gave you in the beginning of this session also and we have already discussed about them in our previous session also in detail.

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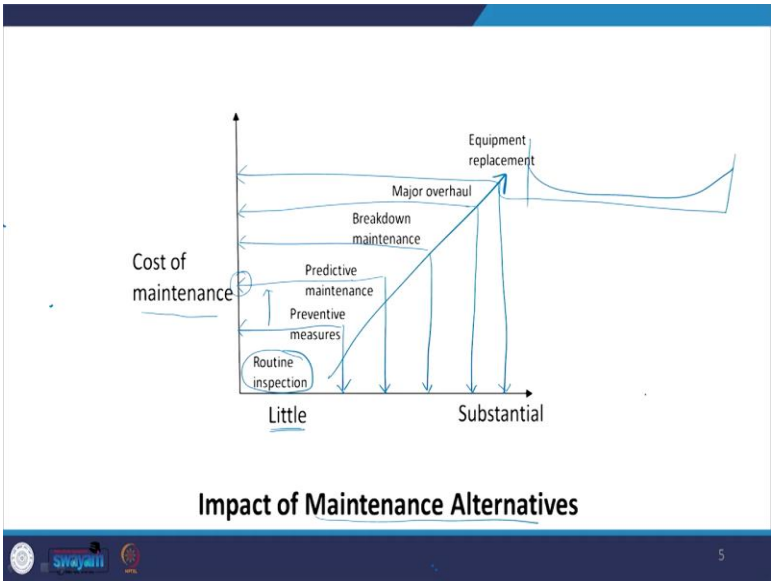

So, based on the impact of maintenance alternatives and the cost of maintenance, let us see how these different types of maintenance plans are going to help us. So, the impact of maintenance alternative is very low when we are having the routine inspection. And you can see that this is the direction of movement, the cost of maintenance in case of routine inspection is very low because you just need to see that all your wires are properly connected, the coolant level is proper, the oil level is proper, the pressure in your tires that is proper, so just by visual inspection you can see all these things.

So, almost 0 cost is involved in the routine inspection, almost 0 cost unless until you are using any other special equipment for checking the particular activity, particular equipment, etc. Otherwise it is having a very minimal cost. But though it is important, it can be the first indicator about the requirement of your maintenance. But on the overall maintenance activity, many a times our visual inspection may not be able to give us the right picture what is happening inside that equipment.

So, it is one of the alternative, but cost is less, therefore the impact is also less. Then the preventive measures it has some substantial you can say impact, but cost also it starts increasing. So, you see this. Now the predictive maintenance, predictive maintenance whenever you are

sensors, which you have installed in your equipment, whenever you get some particular kind of trends, some particular indicator that, yes, there may be a possible failure, then you will go for immediate kind of repair.

So, you have a substantial improvement, substantial impact on the maintenance activities, and because many a times predictive maintenance are not planned properly, because it is just before the breakdown maintenance. Whenever you get a signal that, yes, the problem may happen tomorrow. Like in various civil structures, we use the preventive maintenance very effectively, like in bridges.

So, we put sensors in the bridges, in the pillars of those bridges, whenever some kind of crack starts coming, so those sensors will give you the signal that this particular pillar requires some kind of maintenance activity. So, otherwise we do not have any system of preventive maintenance of pillars of those bridges. But because of predictive maintenance we do the maintenance activity.

So, because there is a possibility of fault, there is a possibility of accident so obviously, you can understand the impact will be substantial. And obviously, since it is not planned, so you have to do it in a hurry, and therefore the cost is also considerably higher than the preventive maintenance cost. Then comes the breakdown maintenance. Here, because equipment has failed now and equipment has failed, so whatever maintenance activity you undertake that is going to give you substantial result.

Substantial result means that will help you in relocating or fixing the problem and your equipment will start working again. So that is the meaning of substantial impact of maintenance activity. Since it is a break down and therefore it becomes more like a, you can say, emergency service and for that purpose, the cost of maintenance is also going to be high.

And when you have the some kind of major change in your equipment, like you can take the example of a defense equipment, you can take the example of fighter planes, you can take the example of submarines, you can take the example of ship carrier, and all these examples are there where major overhaul is part of their maintenance activity. Depending upon the changing technology you have to do some major overhauls periodically.

Sometime, sometime you read a newspapers you will find that major overhaul may be costlier than the original cost of the equipment. So in that case, you need to take an strategic decision whether this overhaul is required or you need to go for the replacement of the equipment, so final strategy or final is the replacement of the equipment. When you say that this has crossed the limit of overhaul, now the impact, now the purpose of replacing the equipment purpose of doing some kind of overhauling is not going to solve.

In that case, you may finally take a call, okay, let us replace the equipment, let us change the equipment with a new one. So, that is going to ultimately have obviously the substantial impact because now you have a fresh new equipment and a new bathtub will start from this point. Otherwise, for all these stages, before this equipment replacement you will be at different stages of this bathtub.

So, that is another very important discussion with respect to your maintenance planning that how these different types of alternatives are helping you to achieve the objectives of your maintenance plan.

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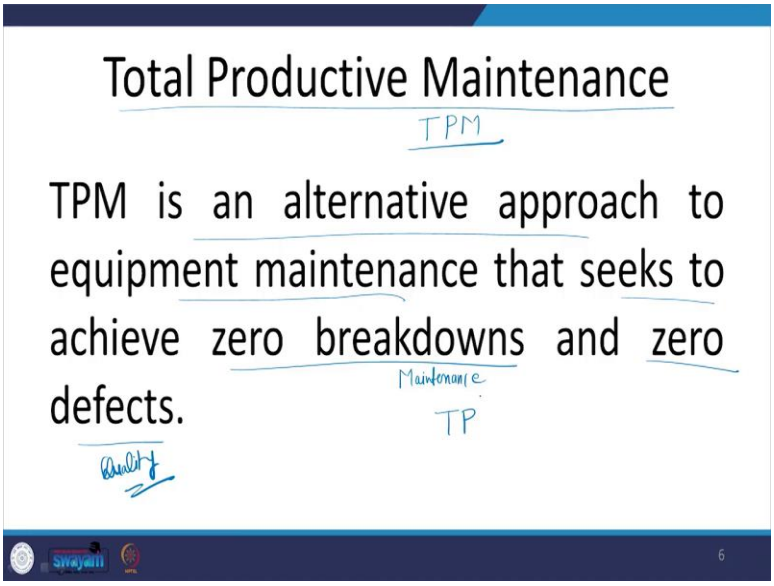

Now finally, as we discussed in the previous session also that the present day, the concept of maintenance, which we are following is TPM that is, Total Productive Maintenance and it is that approach of equipment maintenance that seeks to achieve zero breakdown and zero defects.

Now you see with zero breakdown, it is the issue of maintenance. And zero defect it is the issue of quality. So in fact, when I am talking of TPM, when I am talking of TPM

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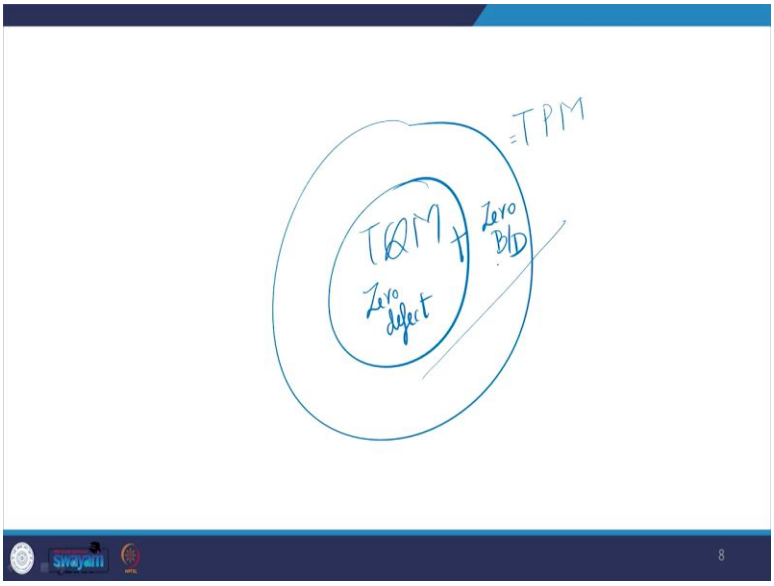

Your issue of, to some extent, you can say that TQM is a subset of TPM. In our quality management discussions, we discuss this very aspect that all departments, all functional area from the top to low, bottom. They need to fulfill the objectives of the organization, particularly in the direction of customer satisfaction.

But now we see, the objective of TPM says that zero defect and zero breakdowns so the combination of these two things, zero defect and zero breakdown gives you the concept of TPM. So with this direction, TPM becomes a much wider concept.

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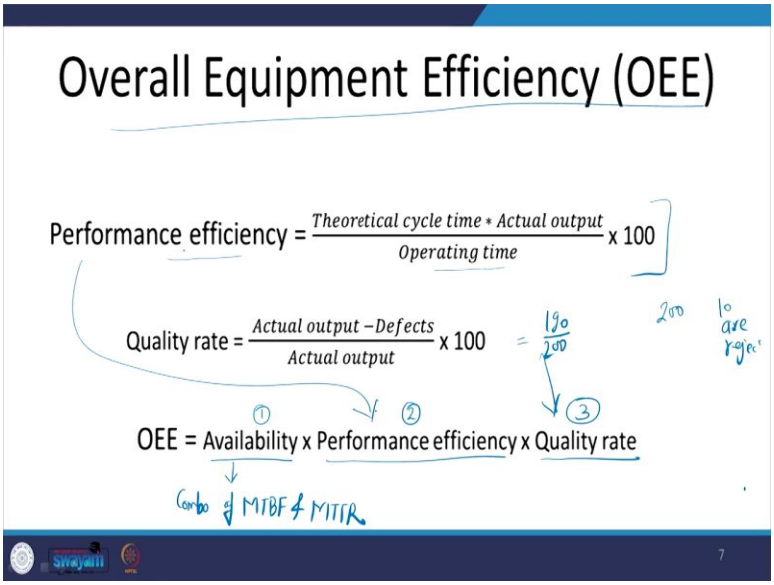

Now to incorporate these 2 things, zero defect and zero breakdown we have a very interesting concept which is known as Overall Equipment Efficiency, OEE that is a very unique and interesting concept which combines these 3 things.

What are these 3 things, one is the availability, which we have already discuss, the combination of, combo of MTBF and MTTR. Then the second is performance efficiency, and the third is quality rate. So, these are the 3 important things which we combine to calculate the overall equipment efficiency of any equipment. Now the performance efficiency is theoretical cycle time into actual output divided by operating time that gives you the performance efficiency.

And the quality rate the actual output minus the defect divided by the actual output. So, like for an example, you are producing 200 output and out of 200, 10 are rejected, so 190 divided by 200 that becomes your quality rate, so that is the quality rate. Performance efficiency is coming because of various types of losses in your activities, because your machine is always not running at the 100 percent performance. So therefore, there are chances that your machine will not have 100 percent performance rating and as a result of that, we will see that some losses are there.

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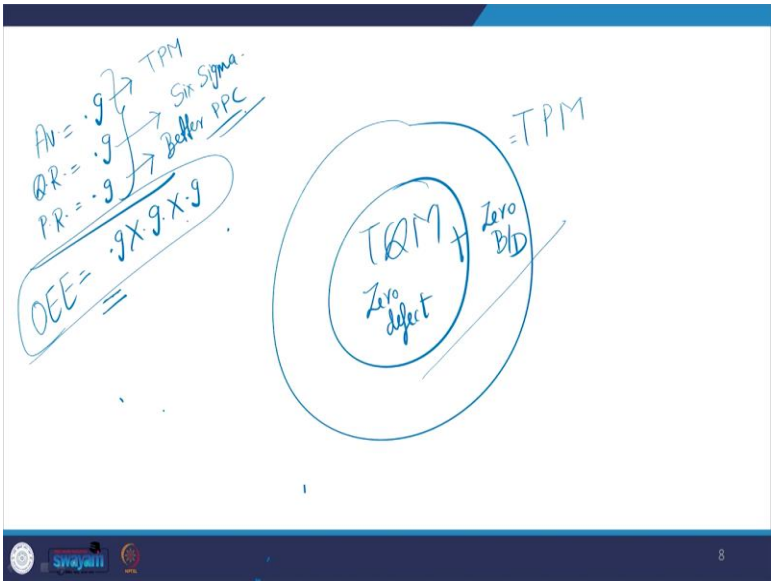

Now we are having a very good system, where availability is 0.9, the quality rate is 0.9, and performance rating is also 0.9. But now you see all these 3 things are very good in their own, availability is 90 percent, quality output is also 90 percent and performance rating is also 90 percent. Now you see, the OEE that is 0.9 into 0.9 into 0.9 and now you can understand that how this OEE of a very good system, individually where the availability is also 0.9, quality rating is also 0.9, and performance rating is also 0.9 but the OEE is coming to be around 70 percent.

So, that is the problem with this calculation that you may see that individually your things are very good, but the holistic measurement is also required so that you can see, no we need to therefore, here we want to have six sigma. Here we want to have TPM, here we want to have better PPC, all these things put together will help us to improve our OEE.

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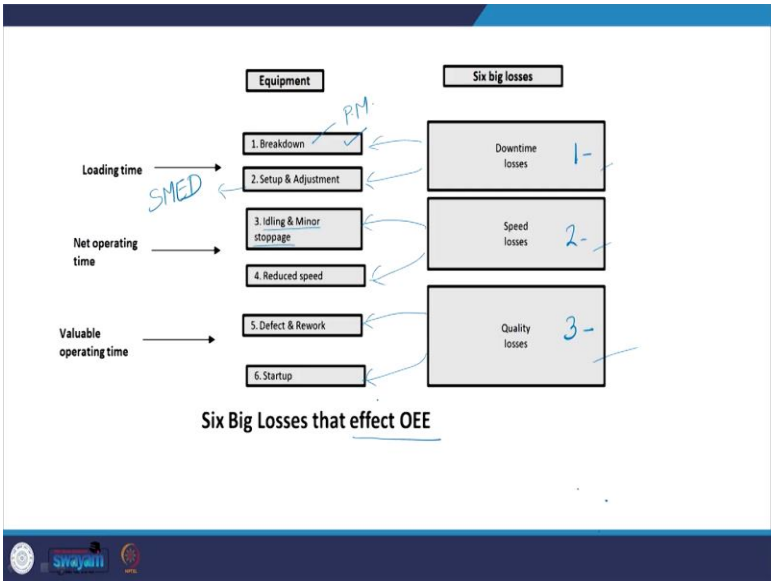

Because let us see that there are different types of losses, there are different types of losses in our production systems which affect our OEE calculations. And what are these losses, like you have breakdown losses and total losses are classified into 3 main categories. 1, 2, 3, and these 3 losses are because of particular issues. What are these, your downtime losses.

Machine is not working, your machine is not working, these are possible because of breakdown or setup and adjustment, machine is under maintenance or the machine is under setup. You are changing the product line and therefore machine is waiting to be started because of change of fixtures, change of dice, etc. So that is the down time losses, that is one thing which is there. Now for break down you need to have preventive maintenance.

For setup and adjustment, you need to have SMED, Single Minute Exchange of Dice, so that you can reduce these downtime losses. The second types of losses are speed losses, where you are not able to operate at optimum speed, the rated speed of your equipment. Sometime you must have observed that when the pressure in your tire, in your scooter, in your two-wheeler is not up to the mark, so you are still running that vehicle, but you are running at a slower speed.

So that is the speed loss and that is like idling and minor stoppage. So, your machine is running, but there is no equipment, there is no work happening on that machine or the minor stoppage you are checking the coolant, you are checking some kind of lubrication activity in your machine. So, for that purpose you have stopped machine for 30 seconds, 40 seconds, 1 minute, etc. So, these

are the minor stoppages. Then the reduced speed, because coolant is not functioning properly and there is a chances of heating of the tools and heating of the tool may be a very damaging activity.

So, you are running the machine, but you are running machine at a lower speed so that overheating does not take place. So, that is a kind of a loss in this case of speed. And the third is quality loss, where you are doing some kind of defects identification and because defects are there, you have to rework your parts, your products, etc. And then, during the starter phase when you are just starting your machine, so as soon as you are starting the machine some initial period is known as transition period, till you come to the steady state when the machine starts functioning smoothly.

So during that phase, whatever products you are producing, there are chances, have you seen any time whenever some kind of screen printing activity is taking place, so when the screen printing activity is taking place initial 4, 5 samples are rejected because by that time the printer is adjusting the screen on the object and after that adjustment of the screen, then all products are coming smoothly, all okay products are coming smoothly. So the initial period, whenever machines are starting some losses are taking place, which are accounted under the quality loss.

So, these are the 3 types of losses which are because of these issues. So, you have to see that how we can minimize all these losses so that our downtime is reduced, speed losses are reduced, and quality losses are also reduced which finally translate into the OEE calculation. So, we need to work on availability, we need to work on performance rating, we need to work on quality output, so that OEE becomes higher for our equipments. You can calculate OEE for individual machine and you can also calculate OEE for your entire plant. So normally, for excellence in maintenance activities we work on OEE for our entire plant.

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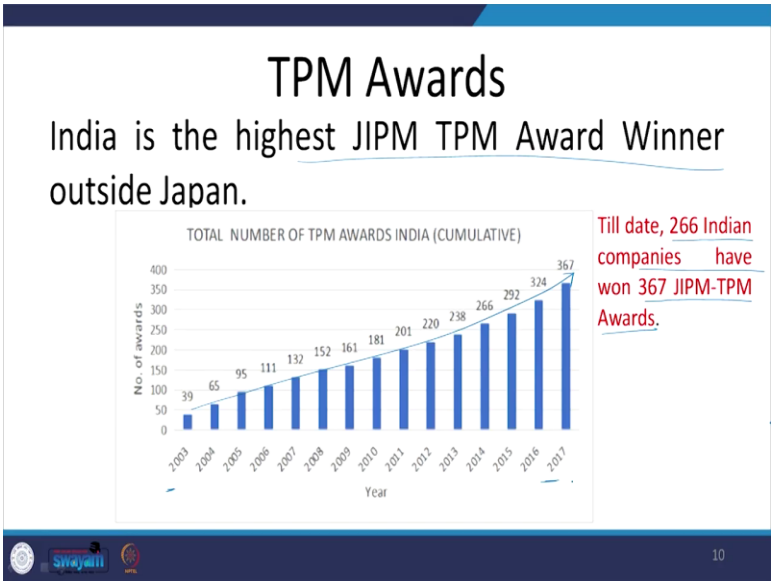

And for that purpose, to recognize the efforts of organizations for excellence work in the field of maintenance management Japan institute of productive maintenance, they came with a TPM prize, TPM award.

And nowadays, TPM award has become very popular across the globe. And not only across the globe, but particularly I am talking of India, that many Indian organizations are also continuously winning, that TPM award. And many Indian organizations are there and you can see that the data available that from 2003 to 2017, total around 266 Indian companies have won 367 TPM awards and continuously this number is increasing.

This number you see is continuously increasing from 2003 to 2017. So, it means that more and more Indian companies are becoming aware and every year, new companies are being added into this list of TPM awards. And TPM award is actually the recognition of your involvement, your particularly towards the maintenance management.

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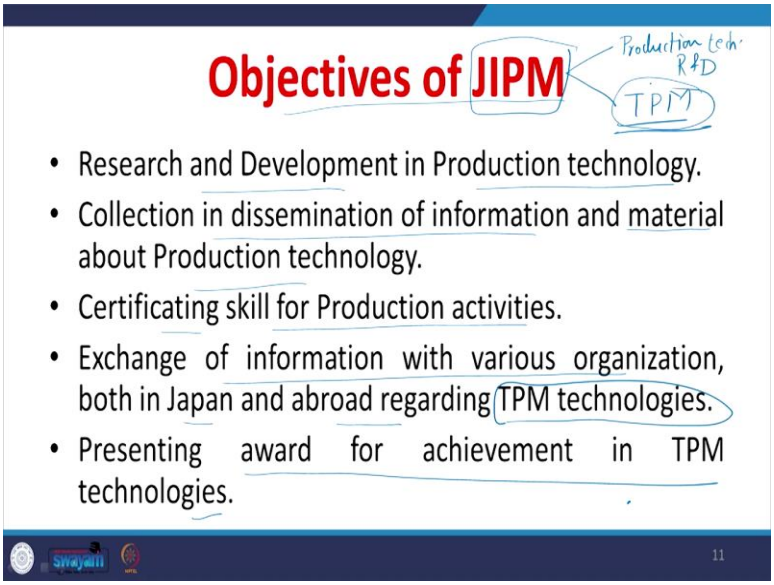

So, the objective because of which TPM award is given by Japan institute of productive maintenance that is a result and development in production technology, collection in dissemination of information, and material about production technology, certificating skills for production activities, exchange of information with various organizations both in Japan and abroad regarding TPM technologies; particularly focusing on total productive maintenance, and presenting award for achievement in TPM technologies.

So basically, this JIPM is dealing in two particular funds, one on the overall production technology R and D, and second on TPM. And Indian organizations have very rightly grabbed the concept of TPM and their numbers are increasing day by day in the list of TBM awardees. So with this, we come to end of this session, where we discussed the calculation part related to measurements of maintenance activities with respect to availability, MTBF, MTTR, and failure rate.

We also saw the concept of OEE, the calculation related to OEE. And finally, we saw the issues related to total productive maintenance, that how Indian companies are becoming part of TPM award list year after year. With this, we come to end of this session. Thank you very much.