Human Factors Engineering

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Lecture - 40
Design guidelines for hand tools

Dear participants of this course, I just covered the vibration portion of environment which we encounter in workshops or in driving or in doing some tasks. And we talked of the types of vibrations, and I had discussed that one is the whole-body vibration; the other is hand-arm vibration. These two are the most important so far as the affecting the performance of the concerned concern in any task which is involved in.

We discussed the whole-body vibration, we talked of the various parameters, and the situations, and the conditions, under which the person is subjected to it, and the interventions we talked of. Also, we talked of what are the ways by which we can decrease these values and see that the person is not put a new difficulty in the task which is performing. Actually, the next one which we are talking of is Hand-arm Vibration. In the current, today’s lecture, we will talk of hand-arm vibration.

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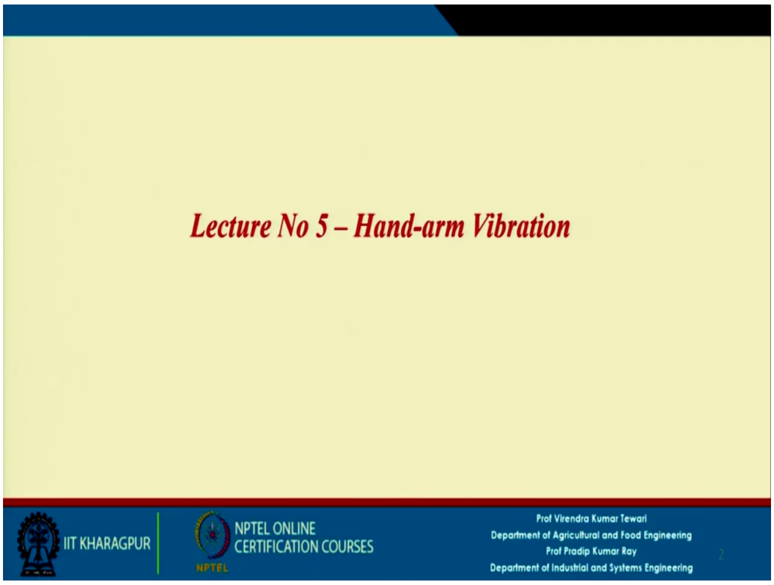

Now, the hand-arm vibration.

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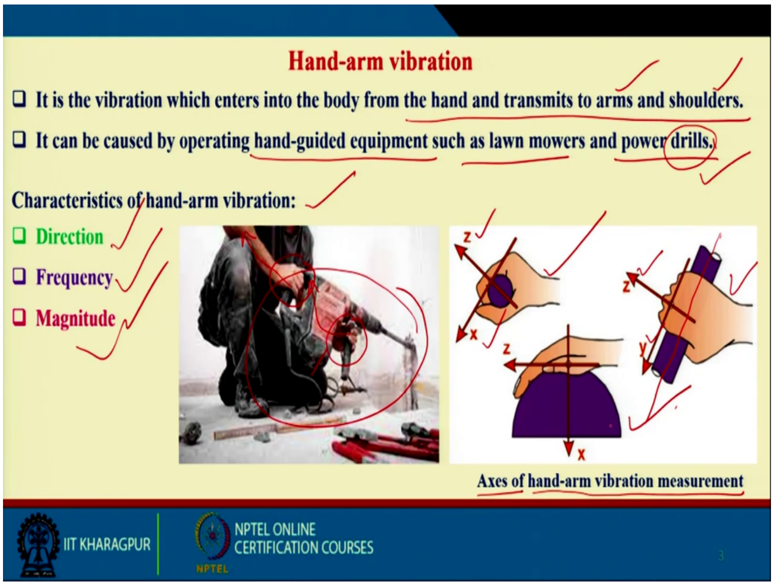

It is the vibration which enters in the body through the hand and transmit to arms and shoulders. When the vibration you can see, how you are holding a particular handle, over your hand holding in this fashion, at a different axis.

Now, you see for example, when the person is doing this task, in a seated posture virtually, in a difficult different body posture. Sometimes, the same thing can be done in a standing posture.

It was shown there that hand-arm vibration; the same person if he stands and then holds then the vibration transmitted to him. It will be in fact more and then the energy requirement will be also varying. He will require higher energy in a standing posture. Maybe he will be more comfortable. But it is a question of debate.

But the fact remains that he is getting the vibration which he is holding over here. So, you can see that the persons both the hands are engaged and from both the hands the vibration will transmit, here to the other hand, and then it will go to the arms and the shoulders, and then this will create problem.

Now, it can be caused by hand-guided equipment. As lawn mowers and power tillers. So, Power drills could also be there, sometimes we use drill bit.

Cursive hand-arm vibration. What is the different wiring characteristic of hand-arm vibrations? In which direction this is working, what is the frequency, and what is the magnitude. These are the characteristics of the hand-arm vibration.

It in fact, it is the characteristics of a whole-body vibration also, we are talking of what is the level of vibration, whether we are getting a vertical vibration, we are getting horizontal vibration at 90º, x and y and z directions. What are the different types of the vibration we are getting?

Then, we talk of the frequency. Frequency is more important when we are considering the response of the person with regard to any job that he is doing. What is the magnitude, which will also talk the ultimate acceleration that we are going to get at this frequency. You see here just an example. The person is holding a cylindrical body, now you see y axis is here, a z axis is here and x axis is inside the plane of this paper.

Similarly, x is here, z is here, and y is just 90º to this in the other direction in the paper. Here also, z is here, x is here, and y is in the paper just like this. So, these are the portions hand-arm vibration measurements when we try to get in the different directions of x and z here, y in the other direction; and x, y, and z here, x in the other direction; and x and z here y in the other direction. Now, these are the axis through which we are talking of the direction of the vibration.

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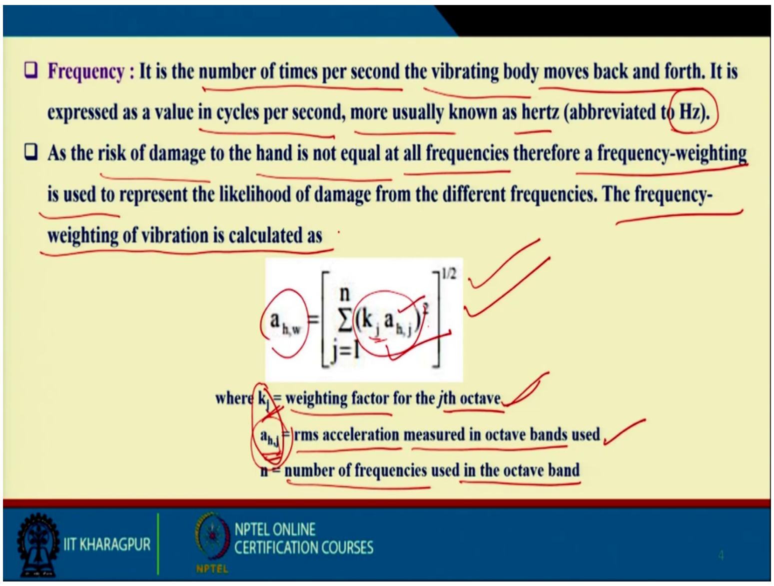

A frequency definition which you can always read and remember is the number of times per second the vibrating body moves back and forth. It is expressed at a value in cycles per second more usually known as hertz and every abbreviated as Hz. The risk of damage to the hand is not equal at all frequencies. Therefore, a frequency weighting is used. The amount of damage to hand or to the other part of the body when the vibration transmits from the hand, because the values are varying and the impact is different.

Therefore, we talk of the instead of having a particular value, we talk of frequency weighting and that frequency weighting is the one which is used weighted frequency. Because we want to know that; well at one location it is slightly more, but in other location it is slightly different, and the other location further different.

When such things are there how to decide which is the mean value? Should we take the mean value? We do not say the mean value, but we say weighted frequency which has a relationship as given below.

$$a_{h,w} = \left[\sum_{j=1}^{n} (k_j \, a_{h,j})^2 \right]^{1/2}$$

where k_j = weighting factor for the *j*th octave

$a_{h,j}$ = rms acceleration measured in octave bands used

n = number of frequencies used in the octave band

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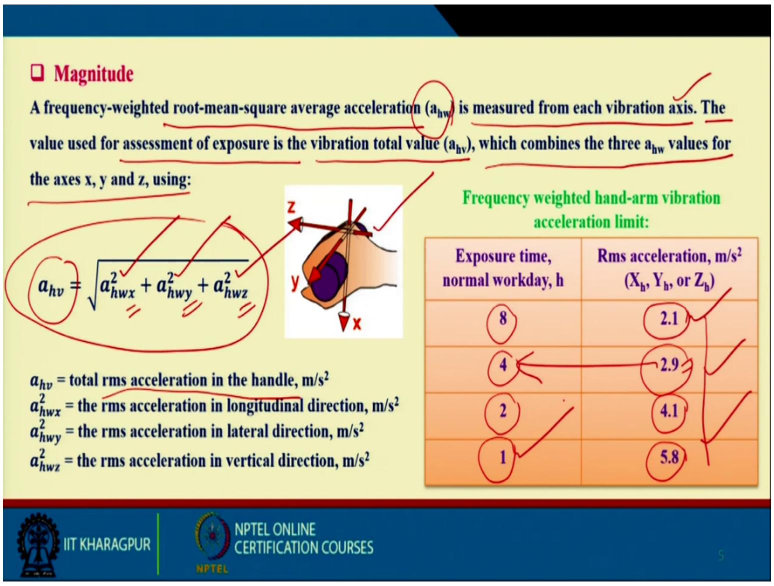

A frequency-weighted root-mean-square average acceleration (a_{hw}) is measured from each vibration axis. The value used for assessment of exposure is the vibration total value (a_{hv}), which combines the three a_{hw} values for the axes x, y and z, using:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

a_{hv} = total rms acceleration in the handle, m/s²
a_{hwx}^2 = the rms acceleration in longitudinal direction, m/s²
a_{hwy}^2 = the rms acceleration in lateral direction, m/s²
a_{hwz}^2 = the rms acceleration in vertical direction, m/s²

Therefore, we need to know what is the total exposure that he will be actually subjected to depending on the value of the vibration, acceleration, weighted acceleration value. We will have to decide as to what should be the maximum exposure in hours or in minutes that a person should be subjected to that particular vibration. Otherwise, it will create undue stress on the body and hence some problem in the body itself. This is given as in x, y, and z.

Depending upon the posture in which he is holding the handle which is vibrating, then you will have to find out the total RMS acceleration.

Now, what is the amount of exposure if the values are x, y, and z, if these are the RMS acceleration values then what should be the level of exposure? How far a person can be exposed to? It is said that the RMS acceleration is about 2.1 m/s^2, then the exposure time could be 8 hours per day.

Now, as it increases say 2.9, then exposure time has simply come to half. Then, as it goes to say 4.1 then the hour is only 2 and if it goes to 5.8 m/s^2 then not more than 1 hour. So, you can see here that the magnitude of the total RMS acceleration is 1, which decides the maximum exposure that the person should be exposed to. Otherwise, it will have undue effect.

Even when 8-hour day a person is having acceleration of 2.1. For a longer period of time and days and months together, this may create some sort of body problem to him. That is why we compromise.

Actually, 8-hour work day is there, but generally people get rest in between and that is why it helps them and if they can do it, they can maintain their composer.

These values are very deterministic and these values can be of 8 hours. But, there one can always argue and say that what is the consequence on which they have been found out, what is the condition on which they have found out, what was the type of equipment which was used.

But then, some researchers have come up with these values and as a guideline we can accept them. You can always test at varying values, and see the energy expenditure of the man, the tiredness of the person or the fatigue level of the person and change if you really find this question of research.

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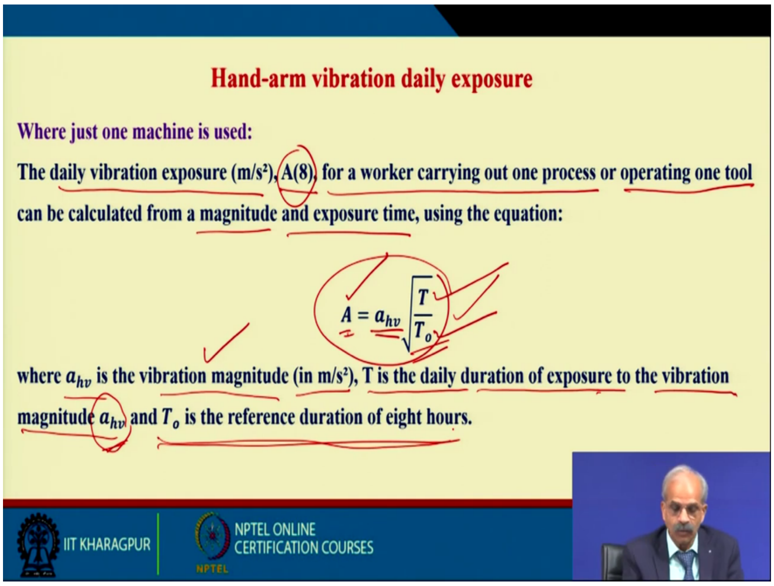

Hand-arm vibration daily exposure.

Where just one machine is used:

The daily vibration exposure (m/s²), A(8), for a worker carrying out one process or operating one tool can be calculated from a magnitude and exposure time, using the equation:

$$A = a_{hv}\sqrt{\frac{T}{T_o}}$$

where a_{hv} is the vibration magnitude (in m/s²), T is the daily duration of exposure to the vibration magnitude a_{hv} and T_0 is the reference duration of eight hours.

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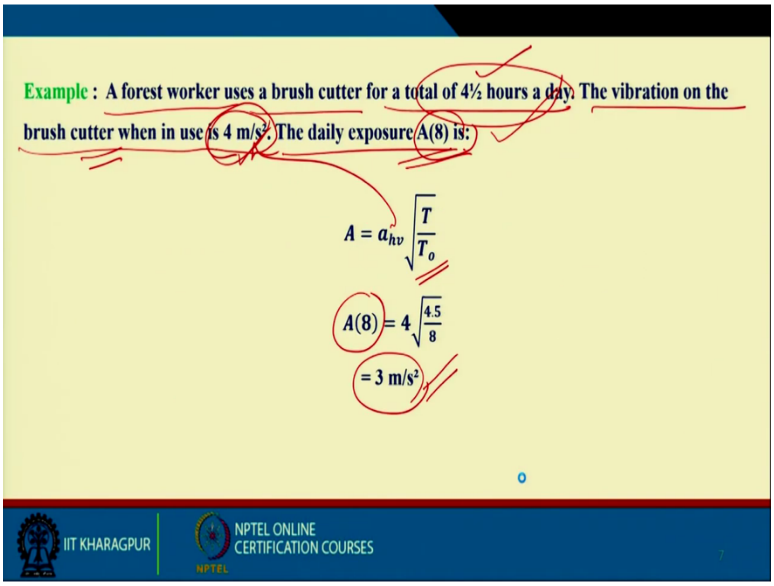

Example : A forest worker uses a brush cutter for a total of 4½ hours a day. The vibration on the brush cutter when in use is 4 m/s². The daily exposure A(8) is:

$$A = a_{hv}\sqrt{\frac{T}{T_0}} = 4\sqrt{\frac{4.5}{8}} = 3\ m/s^2$$

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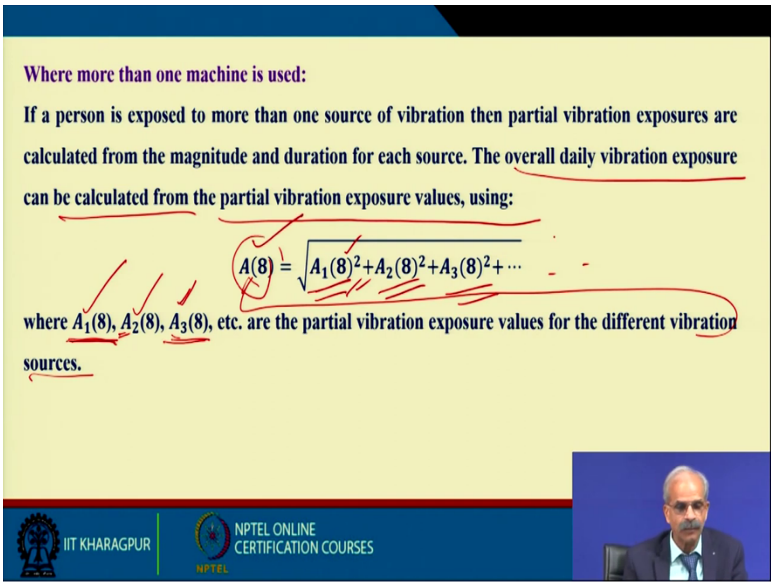

Now, we are talking of the where more than one machine is used. It may happen that the operator is using more than one machine in the whole day. It is possible that while he is doing some manufacturing work in a production shop, he may be using the drill for some time then may be using a power drill for cutting certain things or creating a hole or some other jobs where the different level of vibration he is experiencing in the whole 8-hour day.

The ultimate vibration acceleration that he is experiencing on an average, but we will go for the same RMS value. So, overall daily vibration exposure can be calculated from the partial variation exposure values.

Now, these are the partial vibration exposures in the individual jobs. For example, individual task which he is doing, A2 another task, A3 another task, and so on. If a person is exposed to more than one source of vibration then partial vibration exposures are calculated from the magnitude and duration for each source. The overall daily vibration exposure can be calculated from the partial vibration exposure values, using:

$$A(8) = \sqrt{A_1(8)^2 + A_2(8)^2 + A_3(8)^2 + \cdots}$$

where $A_1(8)$, $A_2(8)$, $A_3(8)$, etc. are the partial vibration exposure values for the different vibration sources.

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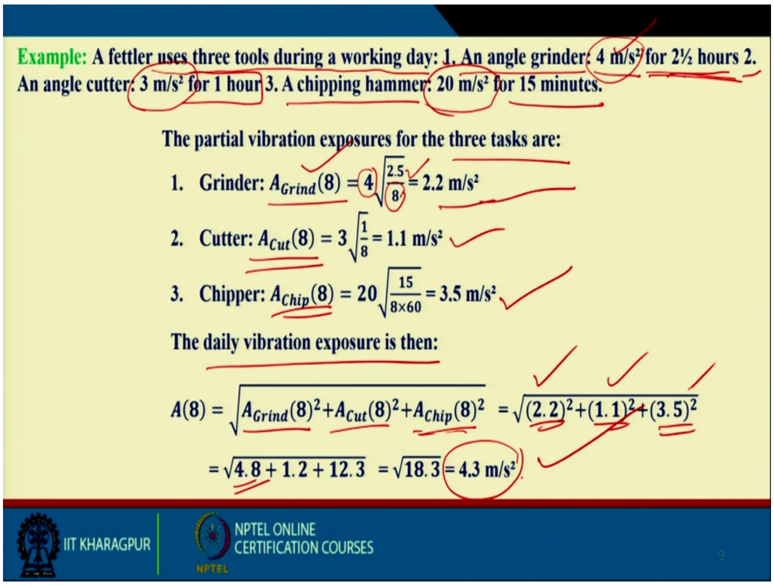

There is another example. A fettler uses three tools during a working day: 1. An angle grinder: 4 m/s² for 2½ hours 2. An angle cutter: 3 m/s² for 1 hour 3. A chipping hammer: 20 m/s² for 15 minutes.

The partial vibration exposures for the three tasks are:

1. Grinder: $A_{Grind}(8) = 4\sqrt{\frac{2.5}{8}} = 2.2$ m/s²
2. Cutter: $A_{Cut}(8) = 3\sqrt{\frac{1}{8}} = 1.1$ m/s²
3. Chipper: $A_{Chip}(8) = 20\sqrt{\frac{15}{8\times60}} = 3.5$ m/s²

The daily vibration exposure is then:

$$A(8) = \sqrt{A_{Grind}(8)^2 + A_{Cut}(8)^2 + A_{Chip}(8)^2} = \sqrt{(2.2)^2 + (1.1)^2 + (3.5)^2}$$

$$= \sqrt{4.8 + 1.2 + 12.3} = \sqrt{18.3} = 4.3 \text{ m/s}^2$$

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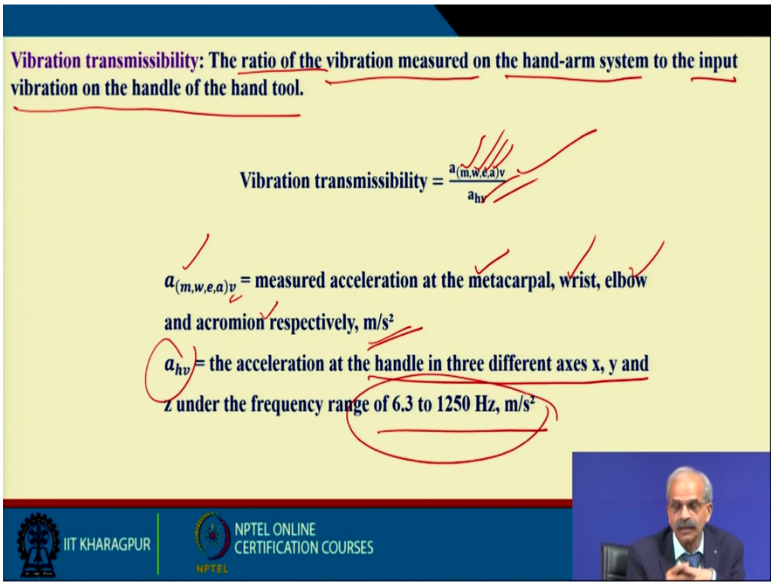

Vibration transmissibility: The ratio of the vibration measured on the hand-arm system to the input vibration on the handle of the hand tool.

$$\text{Vibration transmissibility} = \frac{a_{(m,w,e,a)v}}{a_{hv}}$$

$a_{(m,w,e,a)v}$ = measured acceleration at the metacarpal, wrist, elbow and acromion respectively, m/s²

a_{hv} = the acceleration at the handle in three different axes x, y and z under the frequency range of 6.3 to 1250 Hz, m/s²

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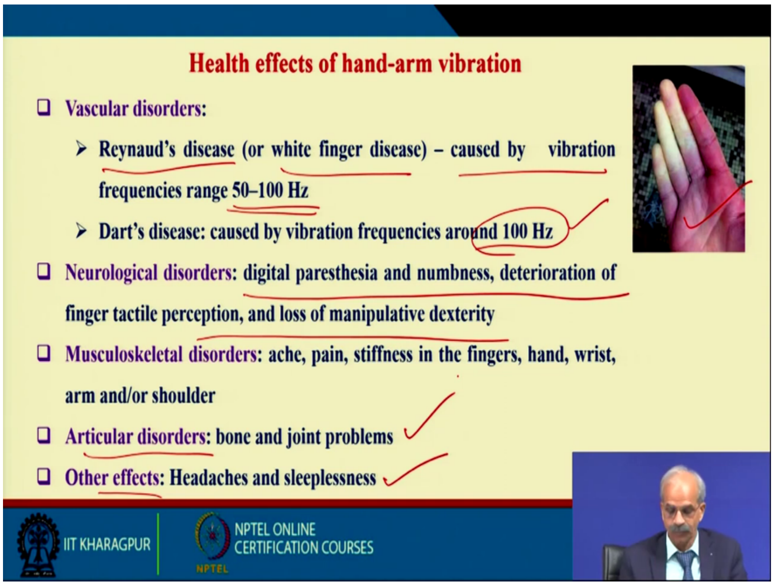

Health effects of hand-arm vibration. There are several health effects. Now, one is given over here- the Reynold's disease or white finger disease that is caused by vibration frequency ranges from 50 to 100 hertz.

Then, Dart disease caused by vibration frequency is around 100 hertz. So, if the frequency is around 100 hertz, you can understand what will be the plight of the fingers of the person. Neurological disorders affects the person because continuously he is experiencing those vibrations which are from the hand, it goes transmit to the body to the shoulders.

Articulate disorders, other effects of headaches and sleeplessness happen to the person if the person is exposed to this vibration. So, as such vibration is very important, and whether it is hand-arm vibration or whole-body vibration, it must be considered by all the designers- whether it is a workshop or the system or the equipment enough intervention must be given to the operator. Otherwise, his health will be affected to a great extent.

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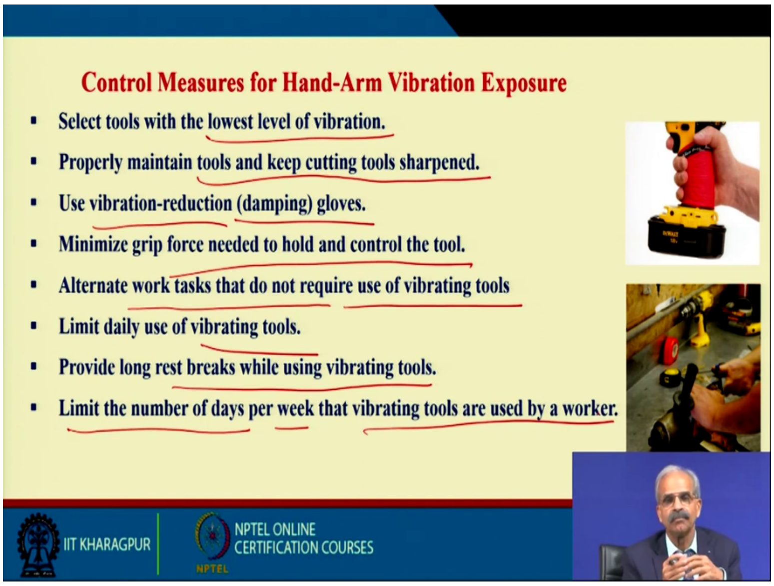

Control measures to hand-arm vibration exposure. There could be various control measures. Select tools with the lowest level of vibration. Properly maintained tools you keep cutting tools sharpened. These things may happen because many times we do exert pressure on them.

Then, use vibration reduction or damping gloves. Minimize grip force needed to hold the control tool. Alternate work tasks they do not require use a vibration tools. Yes, as I said that if he is doing continuously that type of work where he has to pick up 3 types of equipment to handle that, for the job that he is doing in the factory. There may be alternate jobs should be given, and maybe somebody else should pitch in for him, and do the job on that day. Some sort of this management needs to be done.

It is a question of debate as to whether that is possible in the factory or not. But these are the effects which must be considered. Some limit daily use vibrating tools. Provide long rest breaks and using vibrating tools. Then, limit provide long rest breaks.

Limit the number of days per week that vibration tools are used. Between one job to the next job, there should be longer gaps.

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Now, some work we have also done with regard to the interventions (Refer Time: 30:25) and there we are talking of handle as isolators. These will also isolate the vibration from the hand from getting transmitted to the hand. The hand gloves have been found load, where various types of hand gloves are available.

Then, the engine mounting. This is another aspect when you can see here that when the engine is mounted. We need to have the shock absorbers or some of the mountings which should be designed in such a way that they do absorb the low vibration and transmit as low as possible.

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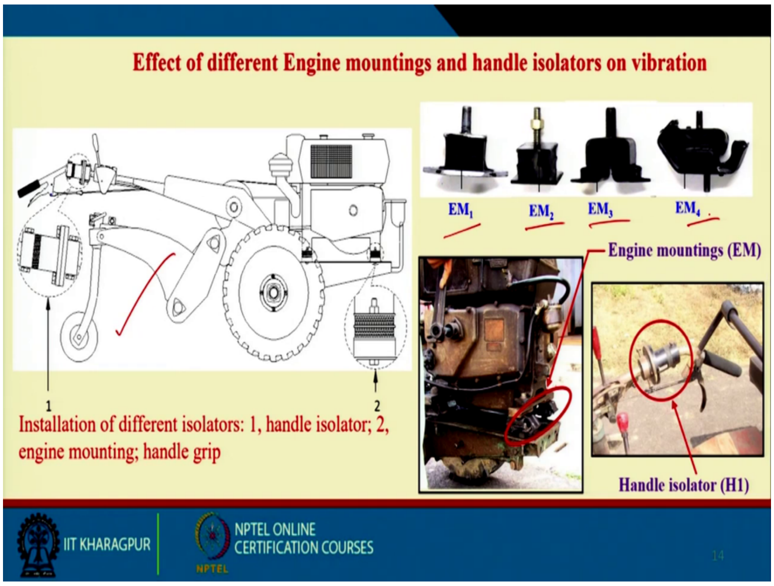

We have done some work in IIT, Kharagpur, particularly with regard to attract a power tiller operation. We had used various types of engine mountings as you can see here M1, M2, M3 and M4. We have tried to isolate and minimize the vibration so that the person can work for a long duration of time.

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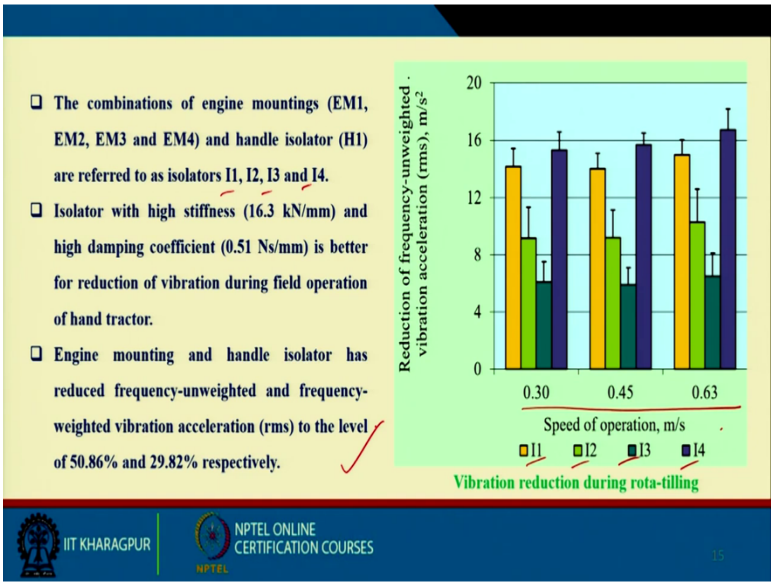

Even the values here are say engine mounting, different, even the speed of operation here it has been talked the speed of operation and the different types of the isolators that we have talked of. Each isolator will affect in its own way. It depends on what type of design that we have given to the isolators.

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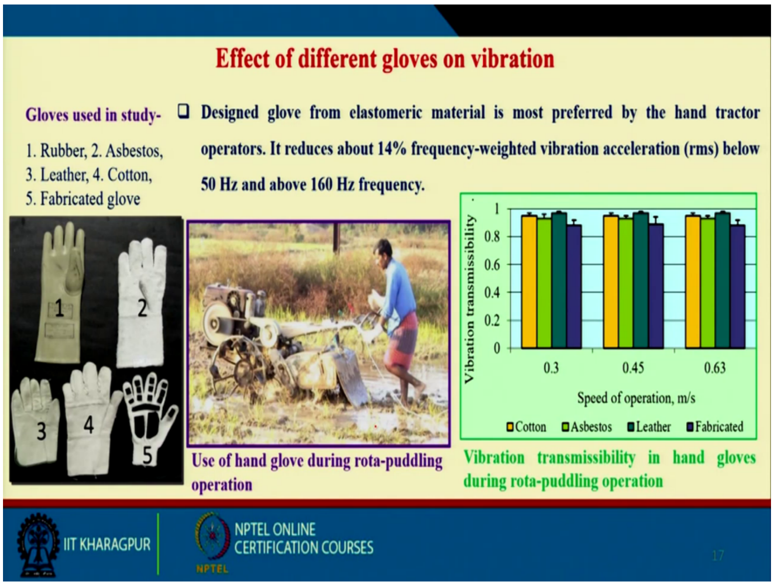

Effect of different handle grips on vibration, which is similarly, an effect of this on the various actual field conditions, what are the job that the person does.