Human Factors Engineering

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Lecture - 39
Whole Body Vibration and Sources of Vibration Discomfort

Dear participants and students who are appearing in this course of Human Factors Engineering, we have created the course in such a way that it will serve everybody's purpose. While my friend Professor P.K Ray has already talked about the environment, now I will talk of another part of environment of the system.

Well, when we are talking of human factors engineering, we talk of human, machine and the environment. Human may be male or female and machine, we are talking machines of various kinds and the environment. Now we need to look at all the 3 factors in such a way that the maximum is obtained of the wholes HME system.

Well, in the environment you have the noise or sound and temperature. I will be talking about one of the factors which is very important and which you encountered in many of the production shops, as well as while tractor driving or sometimes operating a tool of by the hand. So, some of the things which do impact is known as vibration.

So, I will be talking about the vibration, it is effect on the various portions of the body of the human being and the interaction of the person with the equipment and how the vibration gets transmitted.

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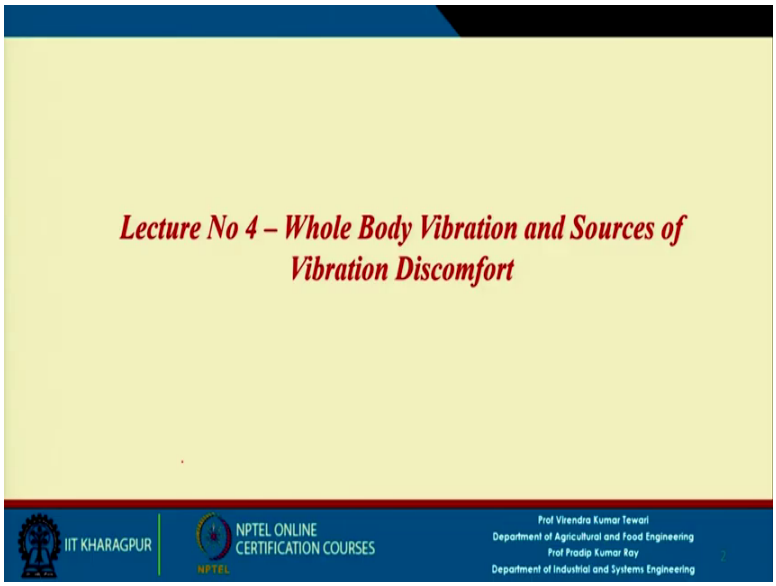

See we will talk about what happens is when a body is seated on a seat let us take the example of tractor, when the tractor vibration from the ground, the vibration which is transmitted in the vertical direction is causing whole body vibration, because the body is in a seated posture and the whole body is lifted up and down in the vibration.

Today we will be discussing whole body vibration and sources of vibration discomfort.

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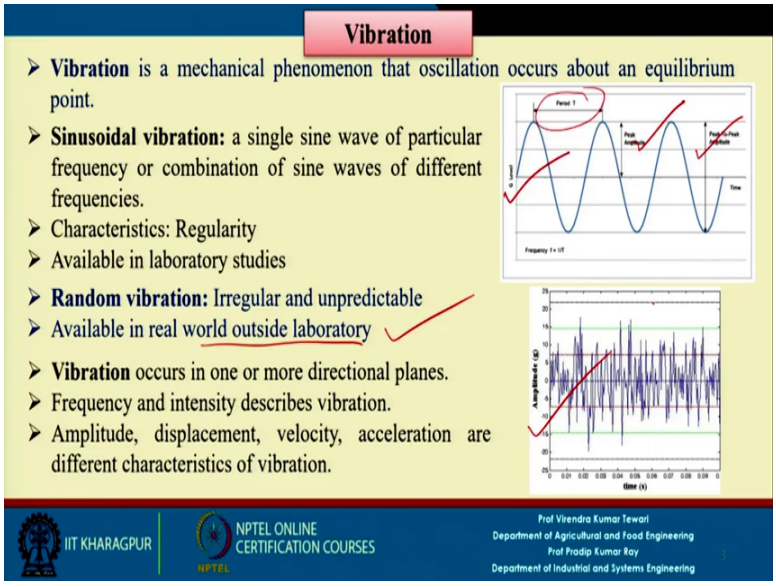

Vibration is a mechanical phenomenon that oscillation occurs about an equilibrium point. Sinusoidal vibration is a single sine wave of particular frequency or combination of sine waves of different frequencies.

Characteristics is Regularity and Available in laboratory studies.

Random vibration: Irregular and unpredictable and is available in real world outside laboratory

Vibration occurs in one or more directional planes. Frequency and intensity describes vibration. Amplitude, displacement, velocity, acceleration are different characteristics of vibration.

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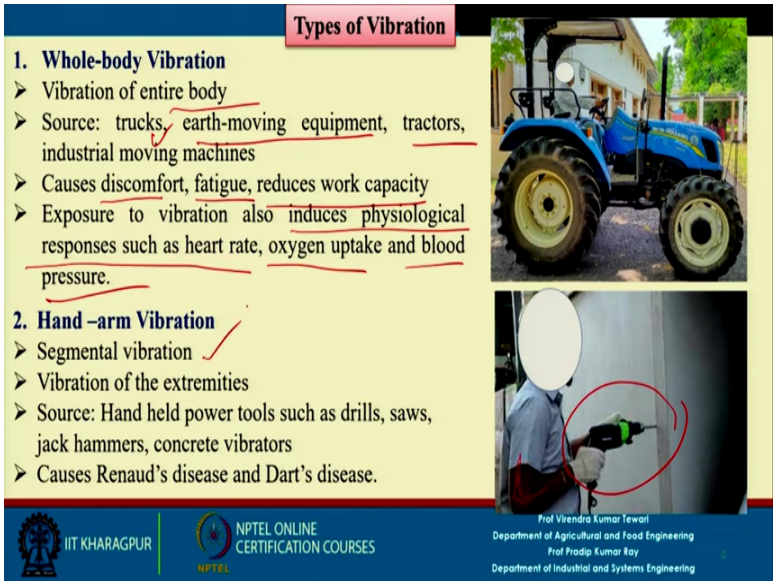

1. Whole-body Vibration

    i) Vibration of entire body

    ii) Source: trucks, earth-moving equipment, tractors, industrial moving machines

    iii) Causes discomfort, fatigue, reduces work capacity

    iv) Exposure to vibration also induces physiological responses such as heart rate, oxygen uptake and blood pressure.

2. Hand –arm Vibration

   i) Segmental vibration

   ii) Vibration of the extremities

   iii) Source: Hand held power tools such as drills, saws, jack hammers, concrete vibrators

   iv) Causes Renaud's disease and Dart's disease.

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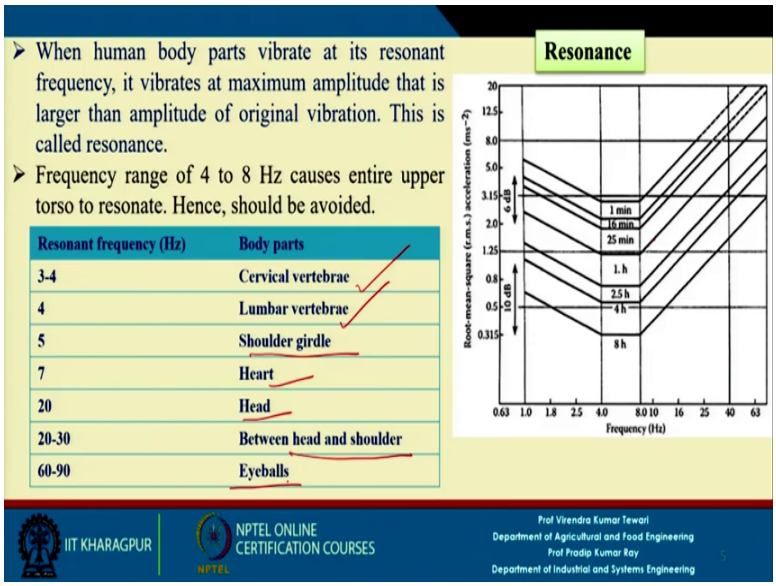

It is said that every part of the human body vibrates at certain resonance frequency. There is a natural frequency of each part of the body and at that natural frequency if there is a vibration which coincides, then there will be resonance.

For example, cervical vertebra, then shoulder girdle, then heart, head between head and shoulder and eyeballs-these are the frequency, which is in fact are the natural frequencies of these parts of the human body.

7 hertz is the frequency for the heart, similarly 20 hertz for head and 20 to 30 for head and shoulder and 60 to 90 for eyeballs.

Now, here some of the some of the details are given here. We are trying to find out what is the time if the person is operating at 1 minute to 16 minute 25 minutes to 1 hour 22.5-hour 4 hour or 8 hour? What is the exposure limit of vibration which the person should be exposed to" And therefore, this gives a guideline.

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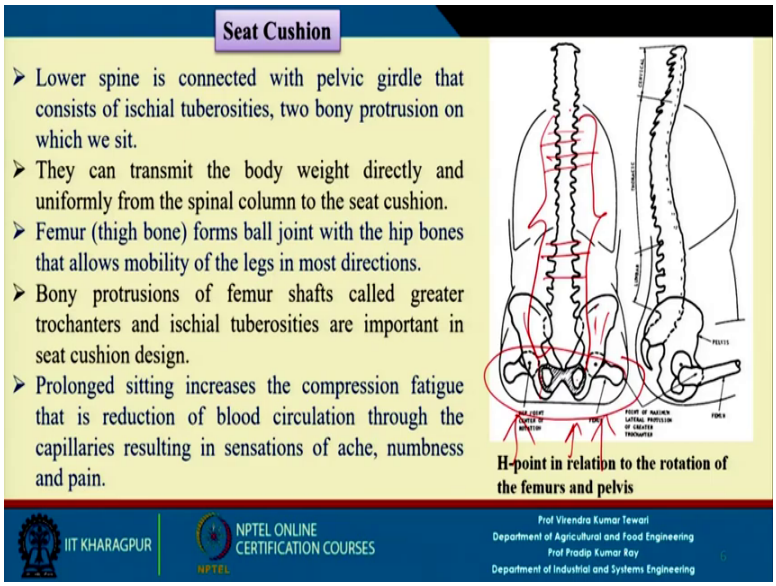

Well, when the person is seated, I am talking of the whole-body vibration you see how the body is situated on the seat. Lower spine is connected with pelvic girdle that consists of ischial tuberosities, two bony protrusions on which we sit.

They can transmit the body weight directly and uniformly from the spinal column to the seat cushion.

Femur (thigh bone) forms ball joint with the hip bones that allows mobility of the legs in most directions.

Bony protrusions of femur shafts called greater trochanters and ischial tuberosities are important in seat cushion design.

Prolonged sitting increases the compression fatigue that is reduction of blood circulation through the capillaries resulting in sensations of ache, numbness and pain.

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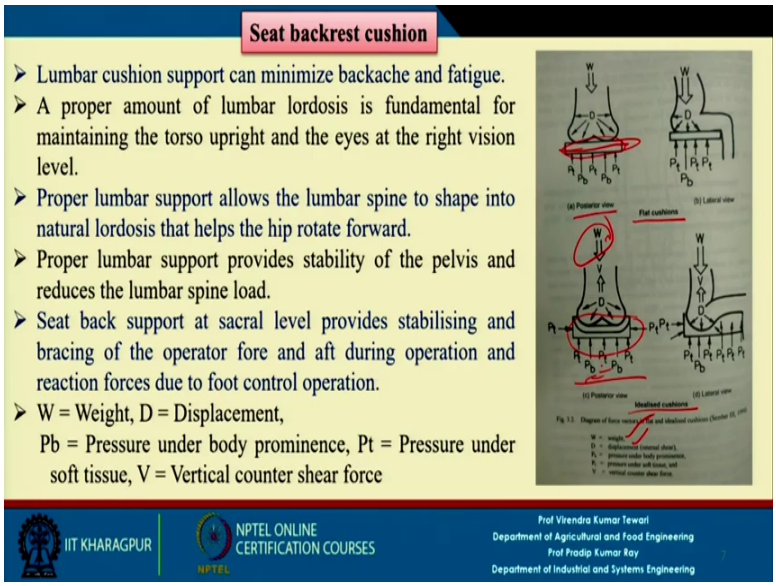

Lumbar cushion support can minimize backache and fatigue. A proper amount of lumbar lordosis is fundamental for maintaining the torso upright and the eyes at the right vision level.

Proper lumbar support allows the lumbar spine to shape into natural lordosis that helps the hip rotate forward.

Proper lumbar support provides stability of the pelvis and reduces the lumbar spine load.

Seat back support at sacral level provides stabilising and bracing of the operator fore and aft during operation and reaction forces due to foot control operation.

W = Weight, D = Displacement,

Pb = Pressure under body prominence, Pt = Pressure under soft tissue, V = Vertical counter shear force.

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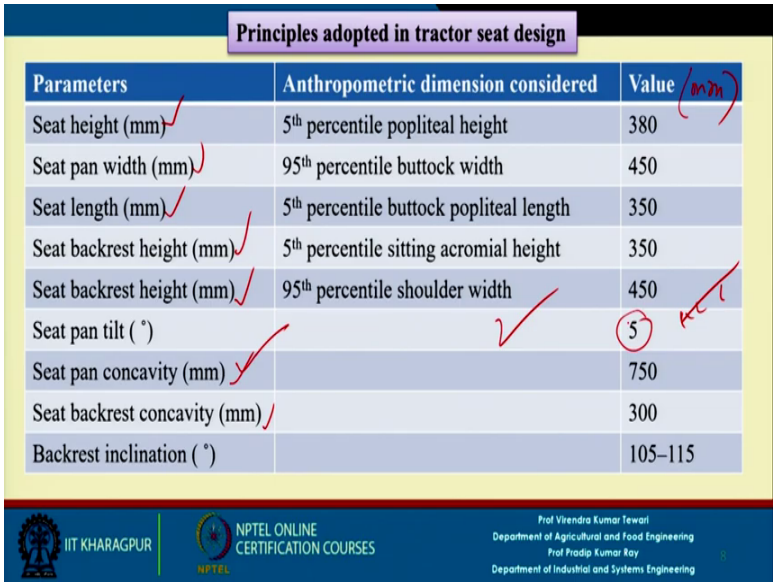

Principles adopted in tractor seat design. These values are in millimeters.

You talk of this in degree tilt. We have taken the data of a large population and then we have come to conclusion about these values.

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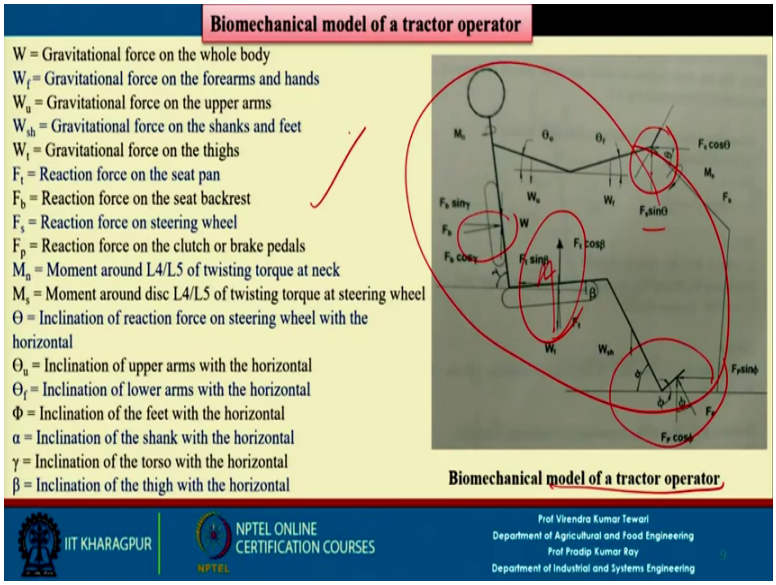

Now, when the person is seated on a tractor seat or for that matter on any seat there is a biomechanical behaviour that we feel, we undergo through or the body undergoes through. Because the person is seated and his legs are on certain foot rest may be on a foot rest may not be on a foot rest, a comfortable foot rest or an oddly kept foot rest he may be having- properly proper positioning of his thighs and proper positioning of his two arms while working.

That is why when we show you see the biomechanical model of a tractor operator, we are showing that the various position when the person is operating; you see what is the position of that when he is scratching with the hand. You can see what sort of forces that are being encountered because he is applying force while he is starting the steering handle and then the location at the seat at the back rest. There are certain forces which are supporting the body, at the this position certain forces, which are supporting and at this location where the foot rest.

When we are considering this, we consider each and every aspect of the persons behaviour.

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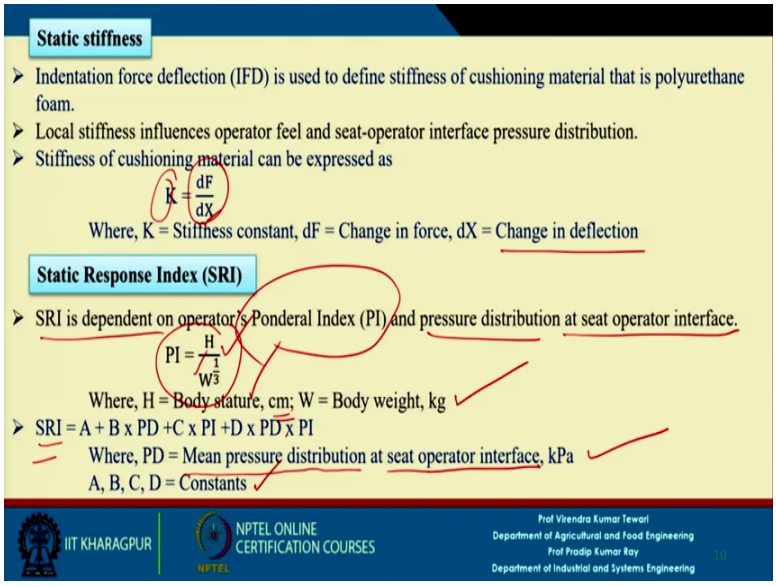

Static stiffness- Indentation force deflection (IFD) is used to define stiffness of cushioning material that is polyurethane foam.

Local stiffness influences operator feel and seat-operator interface pressure distribution.

Stiffness of cushioning material can be expressed as

$$K = dF/dX$$

Where, K = Stiffness constant, dF = Change in force, dX = Change in deflection.

Static Response Index (SRI)- SRI is dependent on operator's Ponderal Index (PI) and pressure distribution at seat operator interface.

$$PI = \frac{H}{W^{\frac{1}{3}}}$$

Where, H = Body stature, cm; W = Body weight, kg

SRI = A + B x PD +C x PI +D x PD x PI

Where, PD = Mean pressure distribution at seat operator interface, kPa

A, B, C, D = Constants

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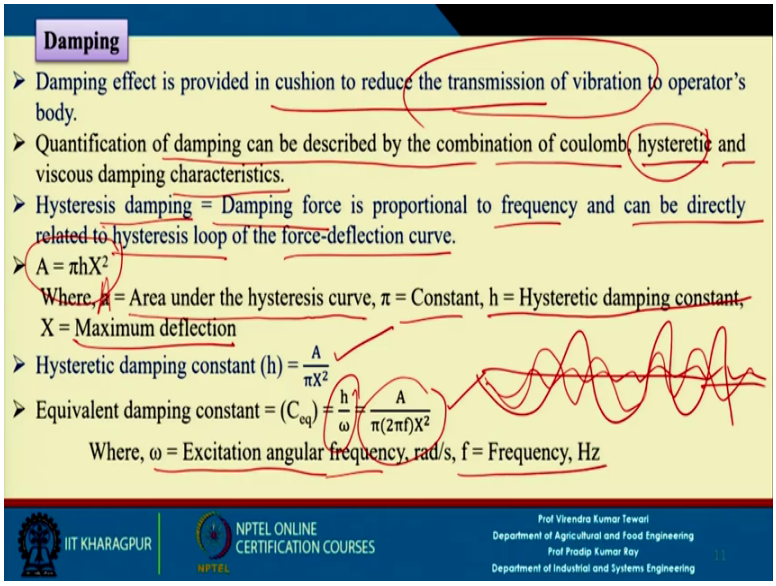

Damping effect is provided in cushion to reduce the transmission of vibration to operator's body. Quantification of damping can be described by the combination of coulomb, hysteretic and viscous damping characteristics.

Hysteresis damping = Damping force is proportional to frequency and can be directly related to hysteresis loop of the force-deflection curve.

$A = \pi h X^2$

Where, A = Area under the hysteresis curve, π = Constant, h = Hysteretic damping constant,

X = Maximum deflection

Hysteretic damping constant

$$h = \frac{A}{\pi X^2}$$

Equivalent damping constant

$$C_{eq} = \frac{h}{w} = \frac{A}{\pi(2\pi f)X^2}$$

Where, ω = Excitation angular frequency, rad/s, f = Frequency, Hz

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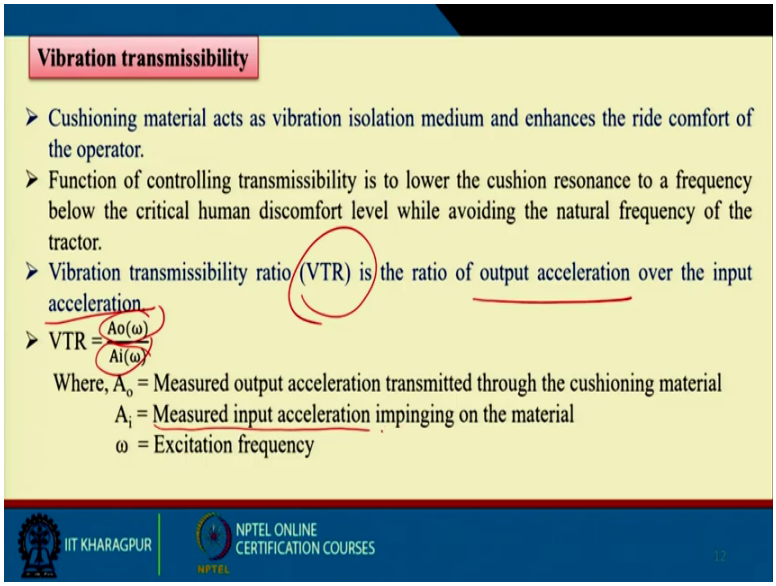

Vibration transmissibility is also very important, because it tell us how much of vibration is actually transmitted to the body and it will depend on what sort of a spring or the spring constant we have used.

Cushioning material acts as vibration isolation medium and enhances the ride comfort of the operator. Function of controlling transmissibility is to lower the cushion resonance to a frequency below the critical human discomfort level while avoiding the natural frequency of the tractor. Vibration transmissibility ratio (VTR) is the ratio of output acceleration over the input acceleration.

$$VTR = \frac{Ao(\omega)}{Ai(\omega)}$$

Where, Ao = Measured output acceleration transmitted through the cushioning material, Ai = Measured input acceleration impinging on the material, ω = Excitation frequency .

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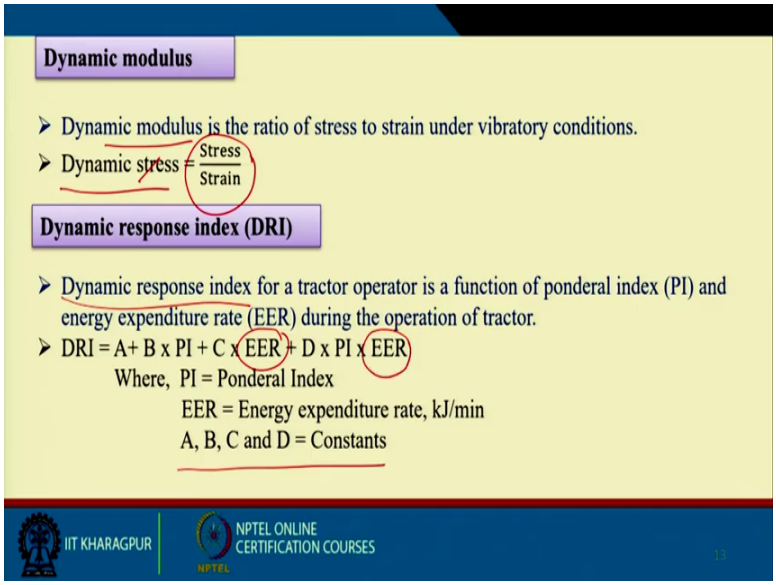

- Dynamic modulus is the ratio of stress to strain under vibratory conditions.
- Dynamic stress = $\frac{\text{Stress}}{\text{Strain}}$

Dynamic response index for a tractor operator is a function of ponderal index (PI) and energy expenditure rate (EER) during the operation of tractor.

DRI = A+ B x PI + C x EER + D x PI x EER

Where, PI = Ponderal Index

EER = Energy expenditure rate, kJ/min

A, B, C and D = Constants

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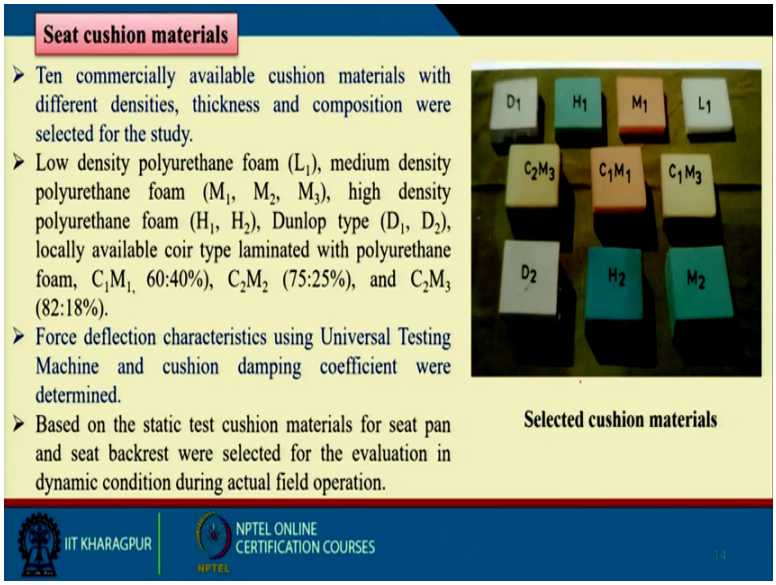

Seat cushion materials. Ten commercially available cushion materials with different densities, thickness and composition were selected for the study.

Low density polyurethane foam (L_1), medium density polyurethane foam (M_1, M_2, M_3), high density polyurethane foam (H_1, H_2), Dunlop type (D_1, D_2), locally available coir type laminated with polyurethane foam, C_1M_1, 60:40%), C_2M_2 (75:25%), and C_2M_3 (82:18%).

Force deflection characteristics using Universal Testing Machine and cushion damping coefficient were determined.

Based on the static test cushion materials for seat pan and seat backrest were selected for the evaluation in dynamic condition during actual field operation.

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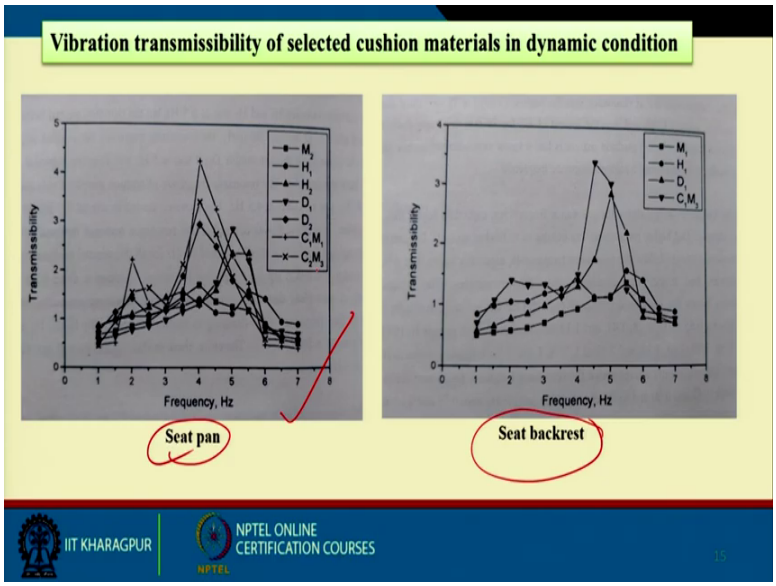

These are some of the values at the seat pan and backrest transmissibility values; because there are two cushions one at the seat pan and the other is at the back rest. So, what is the transmissibility that we are talking of at the different frequency levels has been given in this particular graph.

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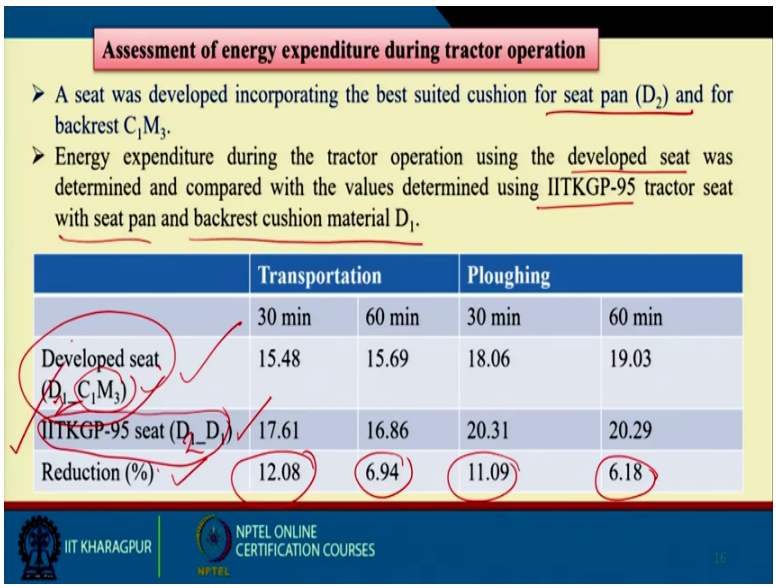

Assessment of energy expenditure during tractor operation- another work was done with regard to expenditure rate during various types of tractor operations. The operation which is most common particularly with the large tractors is that we carry lot of material

in the trailers because they want to utilize the maximum power of the tractor and hence that is acceptable. Only thing is that maneuverability should be taken care of properly otherwise many a times there is overturning of these trailers take place. Transportation is one job which is done for a large duration of the life of the tractor and the trailer and therefore it is important to consider that with regard to other parameters or other operations in the field.

The most difficult operations are deploying operations when you talk of a tractor operator with a certain implement. The transportation one which is applied, which is used for larger duration of time and the plowing which is done- may be first plowing second plowing and may be planking.

First and second plowing are most difficult ones because the condition of the soil is tough and their movement is very difficult and lot of jolting of the body takes comes into play. On the basis of the transportation- 30-minute, 60 minute we have found out different seats. The developed seat is a seat pan. Here it is D_2. These are the values which we get- developed seat and another seat which we developed and the reduction. We had done one seat earlier which we called as IITKGP-95 seat and the one, which is developed again in the case of study where cushion material was also picked up. You can see here that a combination of cushion material was found to be better.

When these two seats were compared, we found that so much of reduction in the transport vibrations. The details of the energy expenditure during the tractor operation using developed tractor seat was determined compared with the value of IITKGP seat tractor seat with seat pan and backrest cushion material. Reduction in the values we got because of the seat in the energy expenditure that person.

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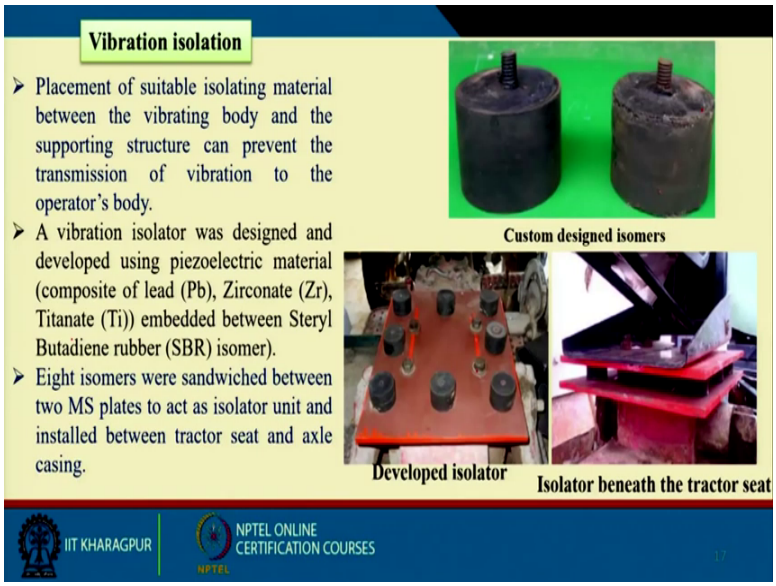

Now, vibration isolation Placement of suitable isolating material between the vibrating body and the supporting structure can prevent the transmission of vibration to the operator's body. A vibration isolator was designed and developed using piezoelectric material (composite of lead (Pb), Zirconate (Zr), Titanate (Ti)) embedded between Steryl Butadiene rubber (SBR) isomer).

Eight isomers were sandwiched between two MS plates to act as isolator unit and installed between tractor seat and axle casing.

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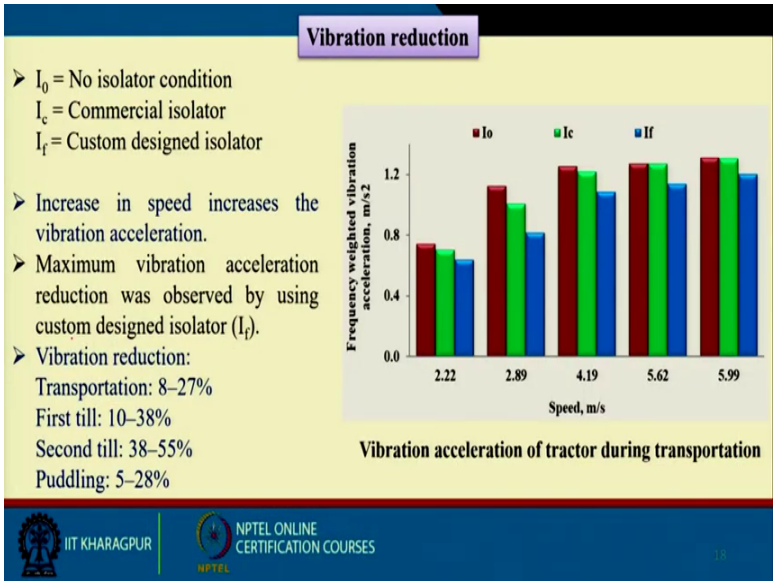

I_0 = No isolator condition

I_c = Commercial isolator

I_f = Custom designed isolator

Increase in speed increases the vibration acceleration. Maximum vibration acceleration reduction was observed by using custom designed isolator (I_f).

Vibration reduction:

Transportation: 8–27%

First till: 10–38%

Second till: 38–55%

Puddling: 5–28%

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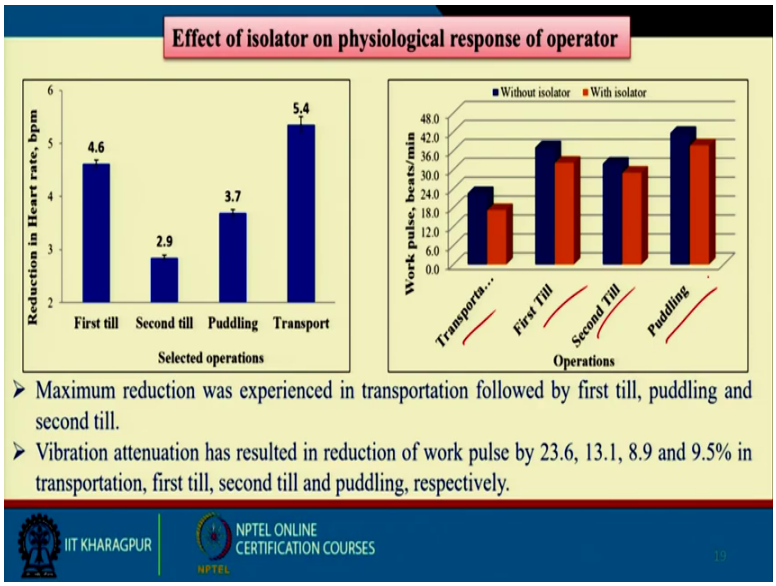

Similarly for isolators effect of isolator physiological response of operator, a similar effect has been found out here that the isolator will definitely give you better effect as compared to different operations.

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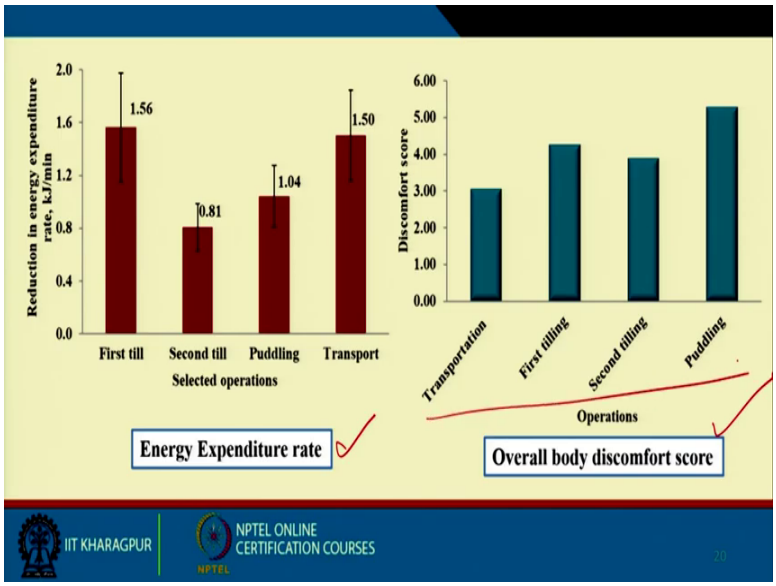

This is about the energy expenditure rate. This is the overall body discomfort as you get into the various operations that we have tested.

You can think of innovative materials which can be used; you can think of different types of tractor seats materials which you can use. And then you can innovate and come out with the best seat, because it is very difficult to say that a particular seat is the best.

And therefore, we take a larger population and try to see that the seat will be suiting to all of them, we do have some adjustment at the backrest and at the vertical position depending upon the height of the person. But otherwise, it is difficult and therefore, this is a very important topic that you must consider.

Thank you very much.