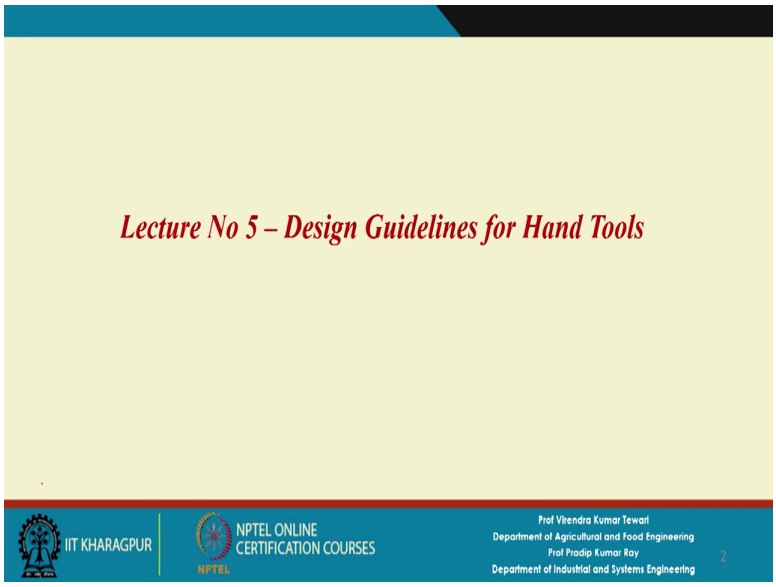
Human Factors Engineering
Prof. V K Tiwari
Prof. P K Ray
Agricultural and Food Engineering Department
Department of Industrial and Systems Engineering
Indian Institute of Technology, Kharagpur

Lecture - 30
Design guidelines for hand tools

Welcome friends, again in the series of tool hand tool designs. In my previous lecture we have discussed about what should be the orientation of the tool, how the tool grips should be designed, what are the anatomy of the hand, what are the different muscles which are coming to picture.

(Refer Slide Time: 00:31)



While we are utilizing the hand, whether the tool which is being operated is not a vibrating tool or not a power tool, maybe just simple hand tool. What is the force application, what is the best way to operate it what are the methodology by which we adjust the design of the tool to fix or fit the task to the person. In fact, we are always trying to say that all the tools are made and everybody can operate.

As I said earlier that one size is not possible to be fit for all, but even then, we design in such a way that it takes larger population in consideration. And does a good job so far as the output of the hand tool interaction is concerned. And that is why you have seen in the

previous lecture, in my previous lecture that we talked of while we are talking about the adjustment or the changes or redesigning the tool or the device with respect to the hand, the fist with respect to the biomechanics of the muscles of the fingers etc.

We do also sometimes take care of the limitations of some of the designs by having some changes in the workspace, may be some of the orientation and environment of the work space in which the task is being performed. Sometimes we also talked of another parameter which comes into play, while not touching the actual design of this the tool is the repetitive task or the training that we give.

Because, many a times we feel that the particular device operation, a particular device or operation of a particular tool. May be out of over confidence we do say that, but that leads to lot of injuries on a long period of time and which we do not realize many a times. And therefore, it is essential to understand that the repetitive task is they are there, then the proper orientation of the hand with the tool is very essential. The force application or the design of the tool fitting the fist of the person or the orientation of the muscles must be taken care of properly.

Otherwise, they will lead to injuries and Musculo Skeletal Disorders and MSDs, will lead to further absenteeism and ultimately loss in pay. Therefore, the designers have to take care of the changes in the design of changes in the workspace challenges in the orientation or the environment of the work or the or avoidance of the repetitive task.

But proper training to the operator for operation of a particular tool in a particular fashion. Now we will also talk of the design guidelines for this in this particular lecture. We will talk of what are the design guidelines we should follow.

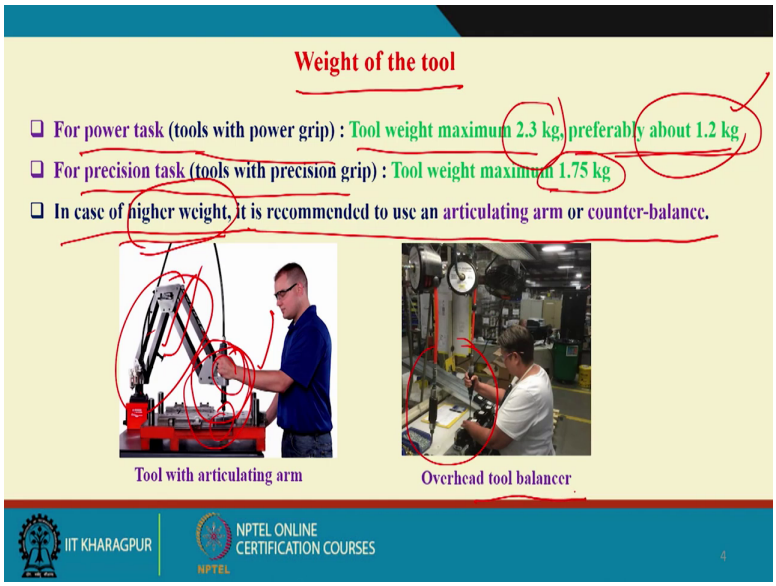
We have talked of the considerations, what are the considerations we talked that the tool must be properly handled and we should avoid the unnecessary odd postures. Now, here we will talk of what are the principles of the design of these tools and how best we can utilize those principles to get a good posture, a best posture for operation of a particular device.

(Refer Slide Time: 04:00)

Let us have a look at the various design guidelines for hand tools. You can see that various types of tools are being handled by the hand, by the same person and you can see the how best the what are the ways in which they are to be handled. Improperly designed hand tools result in increased work-related musculoskeletal disorders (WMSDs) risk, accidents and injuries, and decreased efficiency and productivity. To overcome these drawbacks:

1. Proper design of hand tools
2. Redesign of the work space
3. Training program in tool usage

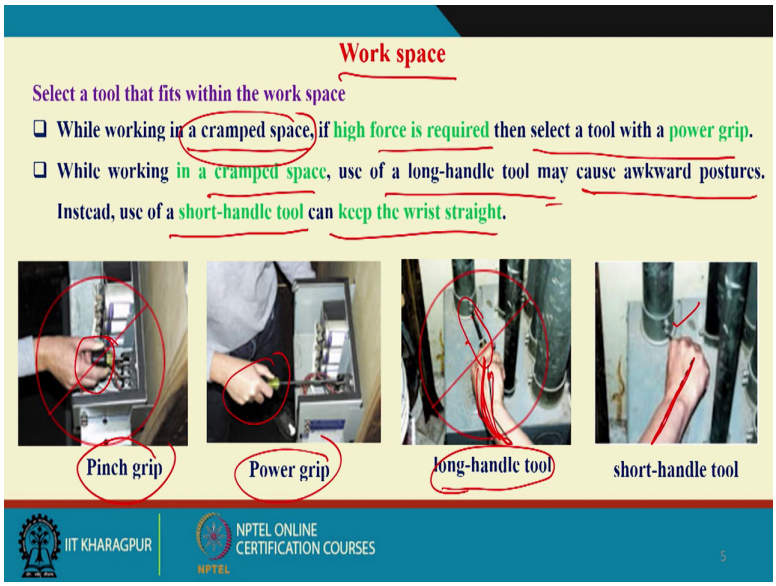
(Refer Slide Time: 05:19)



Se one more important thing which comes into play is the weight of the tool. Yes, it is very important many times a power task, it has been found of tools with power grip. Now, data has been found out tool maximum weight should be 2.3 kg, well, these data which are mostly of the European and taller percent and people with more body mass ratio and people who are more experienced. But there has been preferably about 1.2 kg. Now, this is the one which is the most possible and which can be handled by large persons. Now, when you are talking of precision task, precision with precision grip then tool weight the tool weight should be maximum should be 1.75 kg. While we see that 1.2 kg is the one which should be good for power task or tools with power grips.

Because while we are talking a precision there are many other things even your eyes are concentrating on that, you are some sometimes your fingers are precisely holding that job and trying to see that you overcome the any ambiguity in the operation that is taking place, the precision task that is going on though. Therefore, it is essential that the weight of the tool should not come in the way, if it is heavy, yes it will definitely, if it is lighter then also there is a chance of problem. In case of higher weight, it is recommended to use an articulating arm or counter-balance.

(Refer Slide Time: 10:33)



Workspace: it is not possible to consider and include all the parameters in the design for taking care of all sorts of human being. Therefore, we will have to think of certain changes in the work space, what sort of workspace changes we should make because some of the cramped space, if you have a cramped space, you can understand that you will not be able to perform things properly.

Although, because you do not have enough space to apply the force or to turn the thing or to take care of the integrity of the work that you are doing. And therefore, such a crammed space will hinder your total performance particularly when you are requiring higher force or you are requiring is power grip. So, these some of the things are very essential and need proper consideration of the designer, while you are thinking of the weight, where thinking of the dimensions, where you are thinking of the grip and all those.

And material of construction its repetitive use and its overall use in the whole period of its life, you must think of how it is being used, in what posture it is being used and in what condition, where it in this tool has to be used, what will be that location where it has to be used. So, a cramped space and where you have to apply many times we have seen in repair and maintenance of the tools, we find that the person has to go to a location where he has to apply a force or prepare put a wrench and then try to open.

So, if he does not get a proper space for movement, it will take lot of time at the same time sometimes injury to his hand and elbow as well. And it has been observed by the in some in some cases we have seen intricated places or very cramped spaces where repair maintenance is done. And there only we think that how best one should think of a concurrent engineering; that means, while we are thinking of the design we should also think of the repair and maintenance.

When the installation takes place the person the insulation engineer, the design engineer and the operation person, points of view must be taken into consideration so that they know that while repair and maintenance the person who will repair will not have difficulty in reaching to that particular part with a particular tool or a device.

So, that is what we are talking about. While working in a cramped space use of long handle tool may cause awkward posture. Sometimes we do that because when it is a long a space, where it is cramped space, we say that ok I will put a long. But then it may happen that this long handle will add to the weight of that and maintenance of that will also be a problem, maintenance of that long handle posture of that will be, which will create awkward posture. Yes, it will create an awkward position because you are applying force at distance and you are holding yourself at different location.

So, maybe you will have a such a posture which will not be conducive to your body and then it is very essential that you take care of this. And use a short handle tool can keep the wrist straight, this is a general answer that ok, you keep a short handle tool and use the wrist in a straight posture. But many times, that is also not possible because you there is no definition of short handle, what is the short handle? It will vary from location and the type of tools.

We will talk of operation of an agricultural tool, design of agriculture tool the whole thing and then you will appreciate that how, what is the design of the tool which what is the short handle that we are talking of or a long handle that we are talking of. Just some of the examples which are given here, just for your see pinch grips which are which is like this, then the power grip is the person is holding the power tool then the long handle tool.

You can see here that the person what is the posture in which his hand is and muscles are strained when he has so much of the distance of operation of this, similarly short handle

tools. Yes, it this remains straight, but then many a times when this is something of this position, long position if this is the one and you can reach up to this of course, no problem. You will always maintain this and then you will be able to operate it faster or maybe quickly you can open, suppose you are trying to open a nut over here or a bolt over here, it is possible.

But then if you have done not have enough space and you are talking of using a long handle, then that it will definitely add to weight of that and then it will also give a awkward posture to your hand. And this if the muscles are being pulled for a long duration of time, it will create some sort of injury some sort of pain for that person for a for some time.

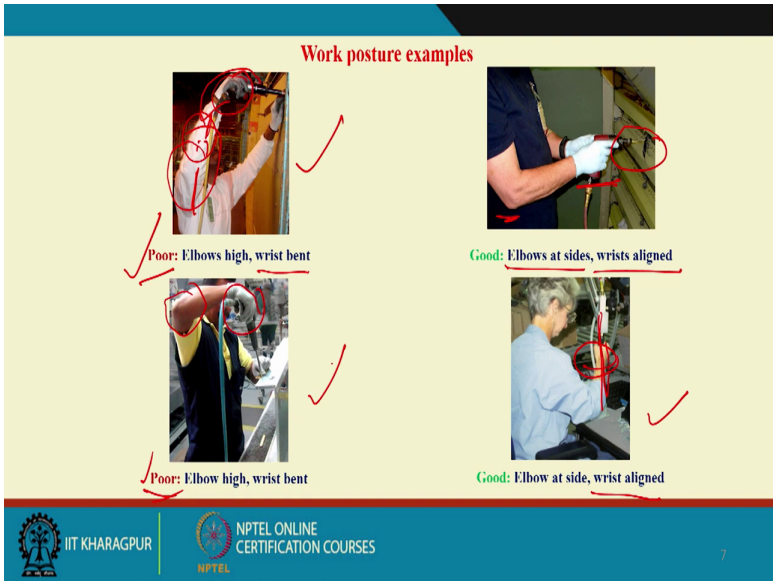
(Refer Slide Time: 15:54)

Yes, so more importance now to the work posture. As I said that work posture has to be the one which comes into play, select a tool that require the least continuous force and can be used without awkward posture. Now, this is what is the method which is utilized. Select a tool that require the least continuous force and can be used without awkward posture.

This should be your aim, but many a times it may not happen. For example, avoid raising shoulders, now you can see here he is in this posture what he is doing and by repositioning your work you can see that work is on a lower surface. Reposition your work piece you can do that, you see by the same thing he has put here, the elbow has

been raised this is what he is saying, that avoid raising your elbow shoulders and elbows. And you see those shoulders and the elbow, if you can redesign the position or positioning your work piece something like this in a tool or handle in such a place then here work push at a lower space. So, then his shoulder is also in proper posture even the elbow is also not raised. It is best in a standing posture how redesigning the work space or the environment. Relaxed shoulders and elbows are more comfortable and will make it easier to drive downward force.

(Refer Slide Time: 19:55)



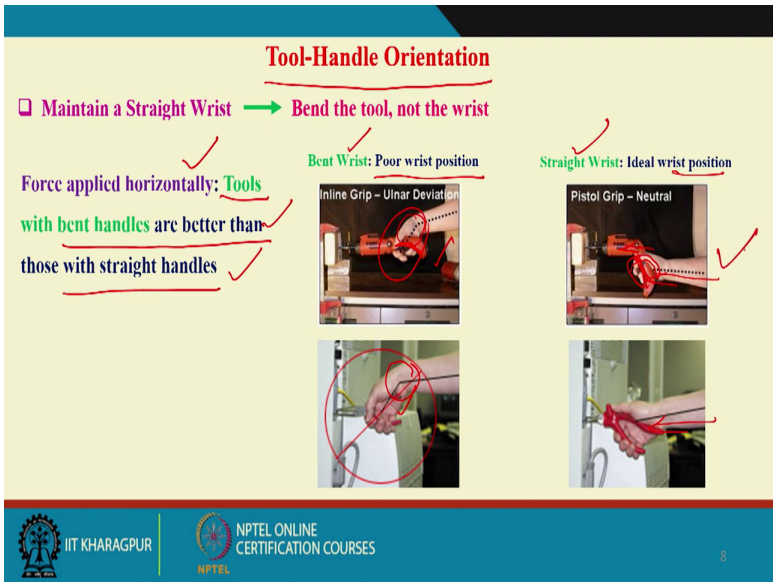
Further examples of work postures, elbow high wrist bent. Now, you can see here in the figure that what is the position of the wrist and what is the position of the elbow which is has been pushed in this very poor posture. Their elbow height wrist bent you can see here. Now, you see these another poor posture, you see these are many a times you might have seen people working like this and we do not know whether that is a correct posture or wrong posture, but these are the wrong postures.

Because the moment your elbow here is lifted you these muscles are under strain, these muscles are under strain and then you will not be able to apply enough force from your wrist here. Because you want certain force to be applied and the force has to come through the shoulders, then only you will be able to get that. Then what is the good one? You see here elbow at sides wrist aligned. See here elbow on the sides of the body of the person here and then the wrists are aligned with the task.

Now, you can apply enough force here and do the task very comfortably. Similarly elbow at side, again elbow has come to more or less side and the wrist is aligned with the task, this is the you can see this is aligned with this, when you are talking of holding this you can see that. And this is a good posture, same thing may be just reorientation of the task gives you a good posture as compared to a bad or a poor posture that we are talking of, they do not want to use the bad word, but yes, a poor posture.

Because it sometimes as I said sometime people who are used to a particular tool for long duration of time, well they do get trained and they give their maximum output, but they unknowingly, they are harming themselves in the long run. They will be able to do that, but they will be harming themselves in the long run and hence we must take care of these while we are thinking of the guidelines for designing of these tools.

(Refer Slide Time: 22:17)

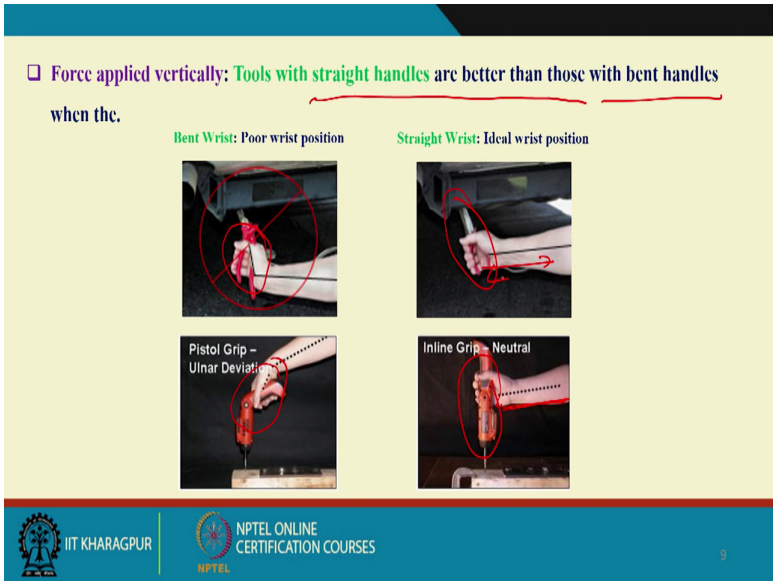


Tool handle orientation, which is operated in the standing posture or a seated posture or in operation, in any posture, but depending upon how the tool handle is oriented with respect to your wrist, with respect wrist or with respect to your arm arms.

Because you need to operate certain amount of force, you need to take care of some of the intricacies of the job which is at present. Maybe you are trying to do a cleaning job in entry intricate place or you are trying to pierce in some of these things for opening a small nut or maybe a bolt and things like that. So, force applied horizontally in the tools with bend handles are better, than those with straight handles. Maintain a Straight Wrist

which means Bend the tool, not the wrist. Force applied horizontally where the Tools with bent handles are better than those with straight handles.

(Refer Slide Time: 24:51)



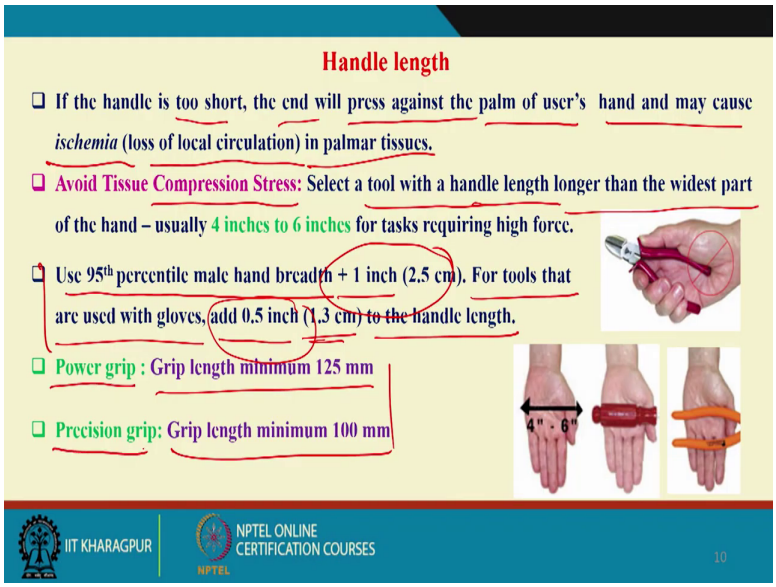
Force applied vertically: yes, sometimes we do apply force vertically. Tools with the straight handles are better than those with bent handles here also. Now, in this case when the vertical force is to be applied, then you see poor wrist position in this case when vertical force is applied.

This is also another one, you can see the wrist position and see how you can do it. Similarly, this you can see here if you are talking of state handles, then these are the positions where it is better now here. This is the one which is better, because this is the one which remains straight, this is the one which remains states and helps you in taking care of the task which is at hand.

So, the orientation of the wrist with respect to your arm is very important when we are talking of force application, when we are talking of the weight of the tool, when we are talking of the dimension of the tool. When we are talking of the adjustment of the workspace, we are talking of the orientation of the tool with regard to other items on the work table and with respect to the person and the type of handles which are given.

These are very important to understand whether the job is to be done in a horizontal portion or in a vertical plane, these are to be considered properly while you are thinking of the design of the tools and devices.

(Refer Slide Time: 26:14)



If the handle is too short, the end will press against the palm of user's hand and may cause ischemia (loss of local circulation) in palmar tissues.

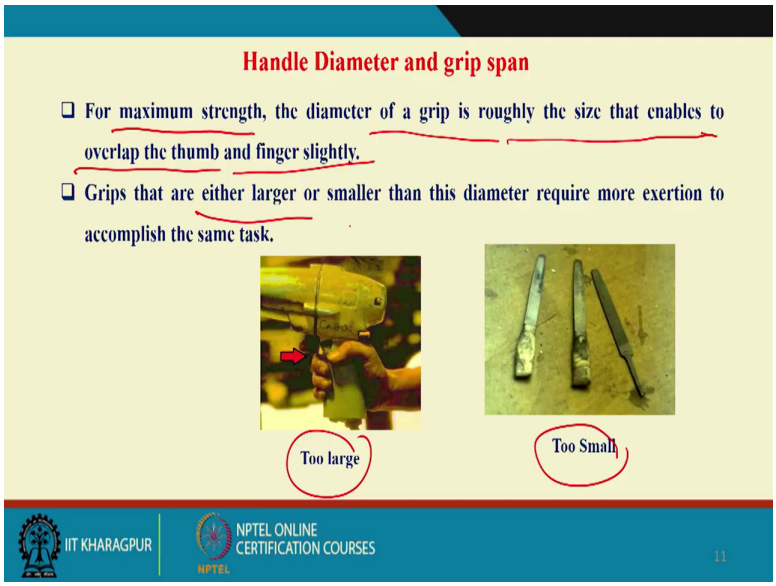
To Avoid Tissue Compression Stress, you should Select a tool with a handle length longer than the widest part of the hand – usually 4 inches to 6 inches for tasks requiring high force.

Use 95th percentile male hand breadth + 1 inch (2.5 cm). For tools that are used with gloves, add 0.5 inch (1.3 cm) to the handle length.

Power grip: Grip length minimum 125 mm.

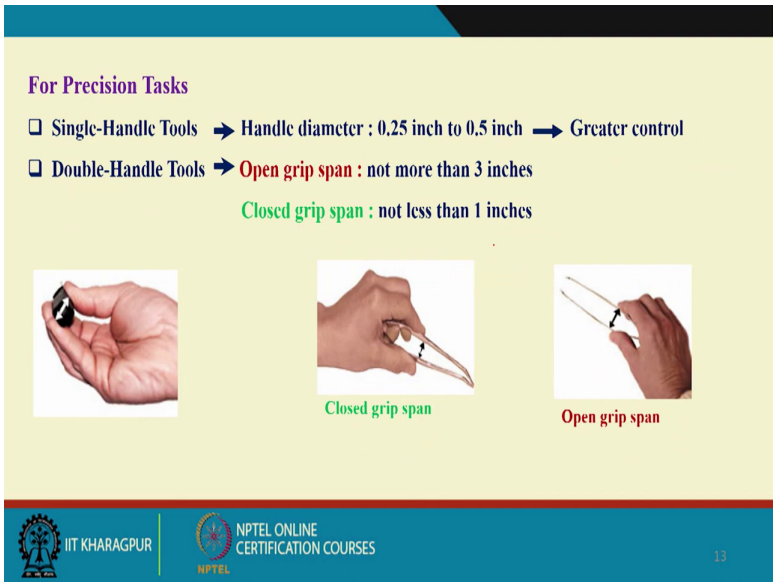
Precision grip: Grip length minimum 100 mm.

(Refer Slide Time: 29:37)



Handle diameter and grip span: For maximum strength, the diameter of a grip is roughly the size that enables to overlap the thumb and finger slightly. Grips that are either larger or smaller than this diameter require more exertion to accomplish the same task.

(Refer Slide Time: 31:50)

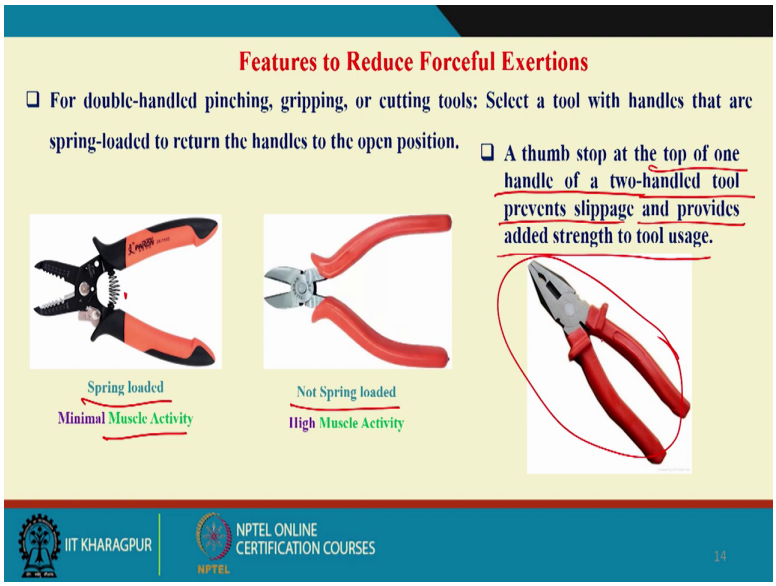


Well, some of the power tasks of single handle tools handle diameter well, this is what greater force and stability single handle tools should have maybe about 2-inch handle diameter. They are talking of and double handle tools, open grip span and closed grip span you can see that the not more than 3.5, not less than 2 inches. The philosophy is the

same which I told you earlier that larger ones will be difficult to handle by the shorter person and slightly average ones will be difficult to be handled by the by that person.

And hence we need to look into that and say that the closed grip span or the open grip span or the double handle tools that we arrive should be carefully designed. These values are guideline values, you might have some sort of addition or subtracting subtraction depending upon the population which you are targeting for this use. Many times, it is essential because we will not be doing for large task which general goes, but if you are talking of specific tasks to be performed, very precision tasks to be performed then it will be essential for you to find out these values.

(Refer Slide Time: 33:20)

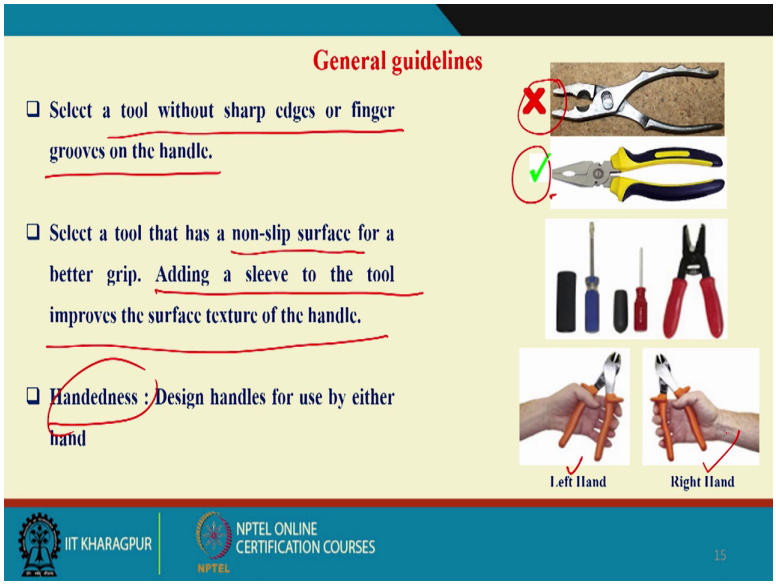


Features reduce forceful exertions:

For double-handled pinching, gripping, or cutting tools: Select a tool with handles that are spring-loaded to return the handles to the open position. Spring loaded means Minimal Muscle Activity.

A thumb stop at the top of one handle of a two-handled tool prevents slippage and provides added strength to tool usage.

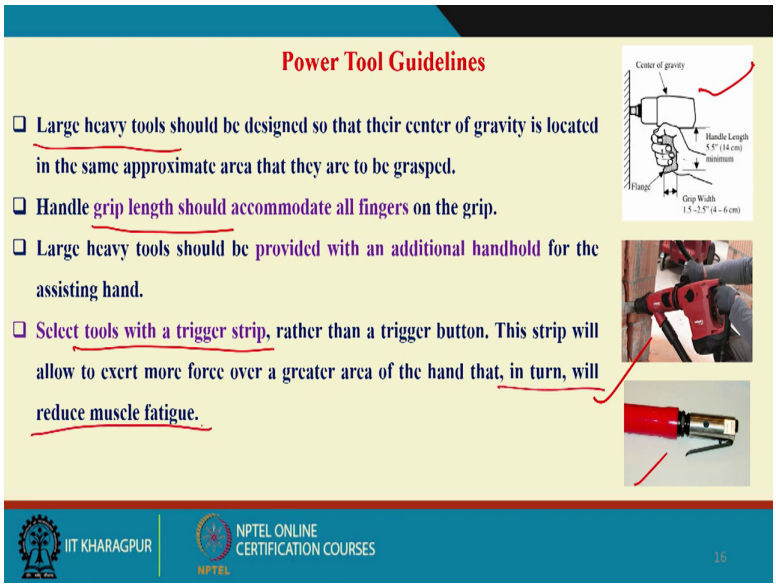
(Refer Slide Time: 34:21)



General guidelines:

1. Select a tool without sharp edges or finger grooves on the handle.
2. Select a tool that has a non-slip surface for a better grip. Adding a sleeve to the tool improves the surface texture of the handle.
3. Handedness : Design handles for use by either hand.

(Refer Slide Time: 35:17)



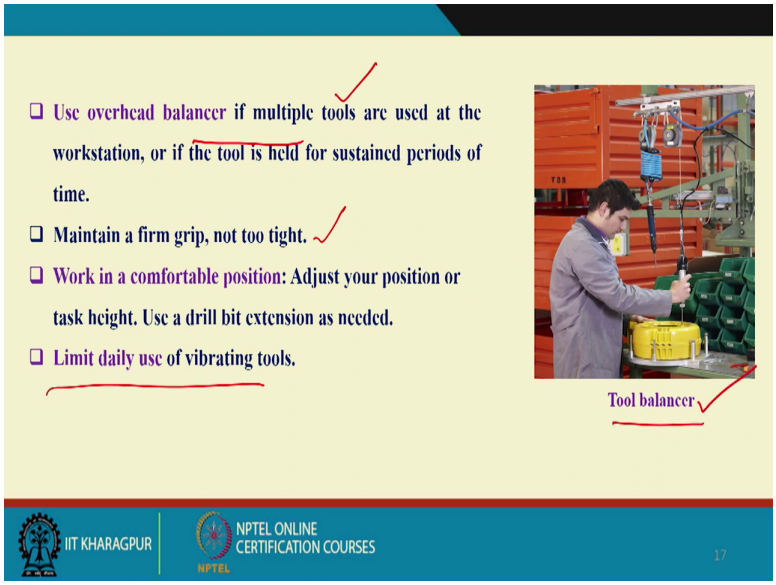
Power tool guidelines: Large heavy tools should be designed so that their center of gravity is located in the same approximate area that they are to be grasped.

Handle grip length should accommodate all fingers on the grip.

Large heavy tools should be provided with an additional handhold for the assisting hand.

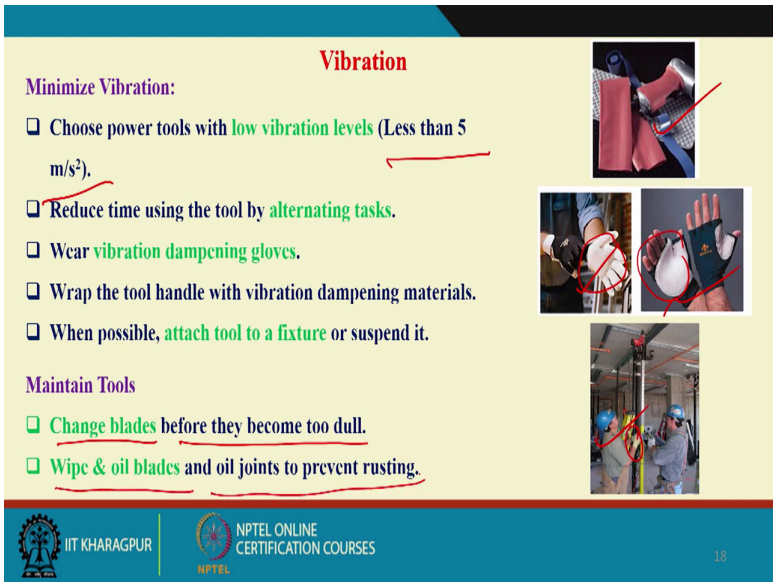
Select tools with a trigger strip, rather than a trigger button. This strip will allow to exert more force over a greater area of the hand that, in turn, will reduce muscle fatigue.

(Refer Slide Time: 36:16)



Use overhead balancer if multiple tools are used at the workstation, or if the tool is held for sustained periods of time. Maintain a firm grip, not too tight. Work in a comfortable position: Adjust your position or task height. Use a drill bit extension as needed. Limit daily use of vibrating tools.

(Refer Slide Time: 37:07)



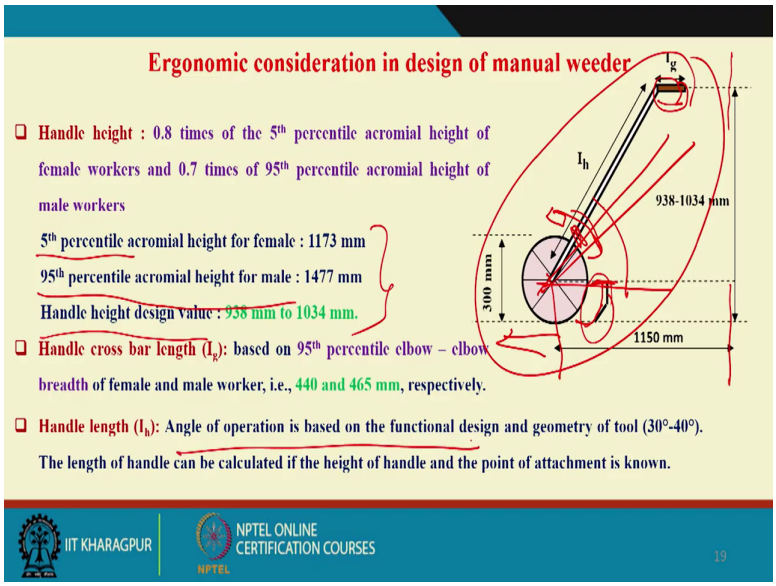
Minimize Vibration:

1. Choose power tools with low vibration levels (Less than 5 m/s^2).
2. Reduce time using the tool by alternating tasks.
3. Wear vibration dampening gloves.
4. Wrap the tool handle with vibration dampening materials.
5. When possible, attach tool to a fixture or suspend it.

Maintain Tools:

1. change blades before they become too dull.
2. Wipe & oil blades and oil joints to prevent rusting.

(Refer Slide Time: 38:32)



Handle height : 0.8 times of the 5th percentile acromial height of female workers and 0.7 times of 95th percentile acromial height of male workers

5th percentile acromial height for female : 1173 mm.

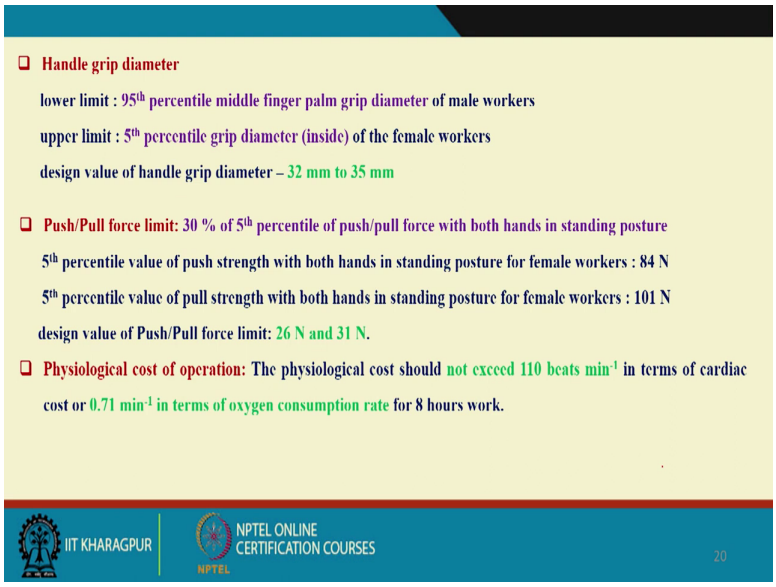
95th percentile acromial height for male : 1477 mm

Handle height design value : 938 mm to 1034 mm.

Handle cross bar length (Ig): based on 95th percentile elbow – elbow breadth of female and male worker, i.e., 440 and 465 mm, respectively.

Handle length (Ih): Angle of operation is based on the functional design and geometry of tool (30°-40°). The length of handle can be calculated if the height of handle and the point of attachment is known.

(Refer Slide Time: 40:26)



Handle grip diameter:

lower limit : 95th percentile middle finger palm grip diameter of male workers

upper limit : 5th percentile grip diameter (inside) of the female workers

design value of handle grip diameter – 32 mm to 35 mm

Push/Pull force limit: 30 % of 5th percentile of push/pull force with both hands in standing posture

5th percentile value of push strength with both hands in standing posture for female workers: 84 N

5th percentile value of pull strength with both hands in standing posture for female workers: 101 N.

Design value of Push/Pull force limit: 26 N and 31 N.

Physiological cost of operation: The physiological cost should not exceed 110 beats min-1 in terms of cardiac cost or 0.71 min-1 in terms of oxygen consumption rate for 8 hours work.