Advanced Design of Steel Structures
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Lecture - 64
Analysis under impact loads

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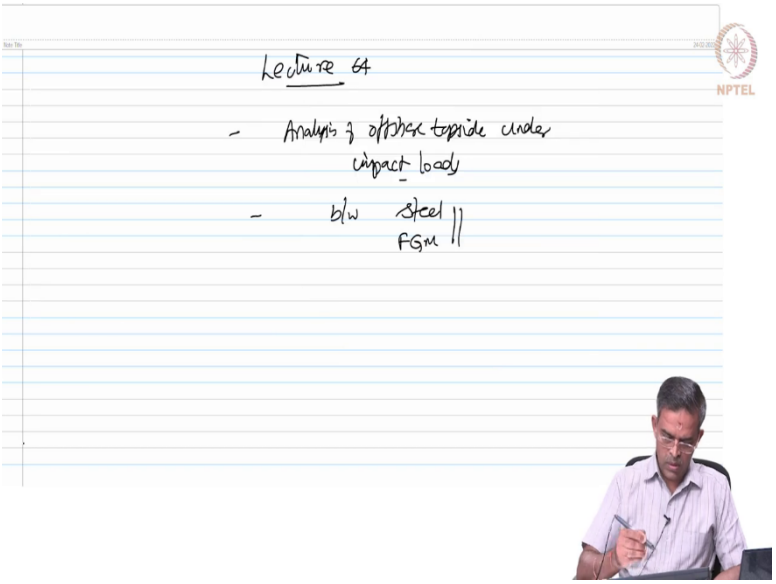

Friends, welcome to lecture 64 of Advanced Steel Design course. In this lecture, we are going to learn a design a example of Analysis of an offshore topside under impact loads; so, thorough design example where the excerpts of the design is being projected and discussed for you. So, in this example we are going to discuss the analysis comparison between steel and functionally graded materials (FGM).

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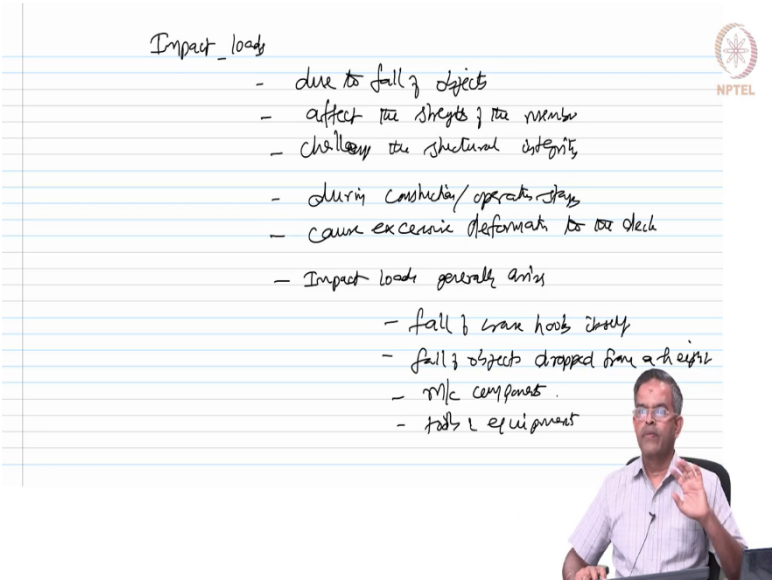

Now, we all know that impact loads happen on offshore structures or buildings due to fall of objects. So, they affect the strength of the member. They also challenge the structural integrity. Now, impact loads can occur during construction or operations. Falling of objects from a considerable height may damage the structural components. It can also cause excessive deformation to the deck. So, the impact loads generally arise from fall of crane hooks itself, fall of objects dropped from a height, machinery components, equipment's and tools.

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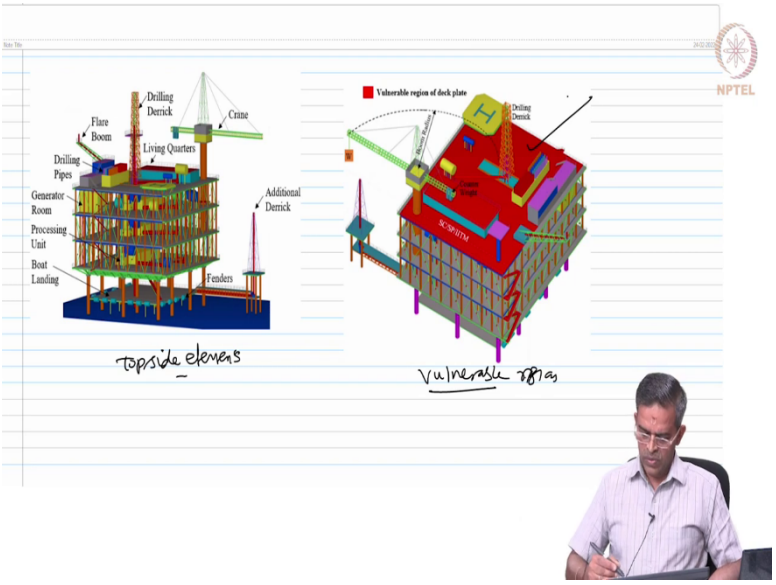

Let us talk a classical example of an offshore platform where the top side is being shown on the figure. So, this is a top side element. On this top side, the vulnerable region for impact loads is being marked. This is a vulnerable region. Let us have a model of this type.

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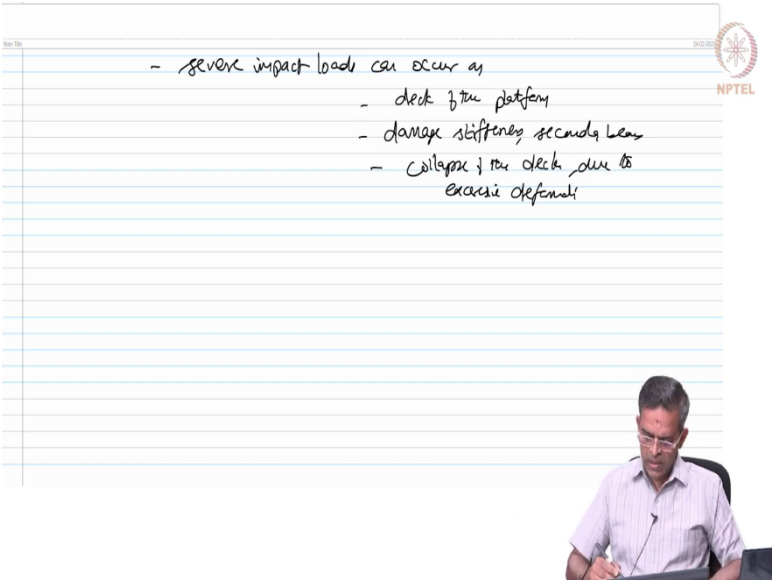

So, friends, severe impact loads can be caused on decks of the platform. It can damage the stiffness; the secondary beams and it cannot also result collapse of the deck due to excessive deformation. Therefore, it is necessary to investigate the strength capabilities of the topside elements to support this kind of impact loads.

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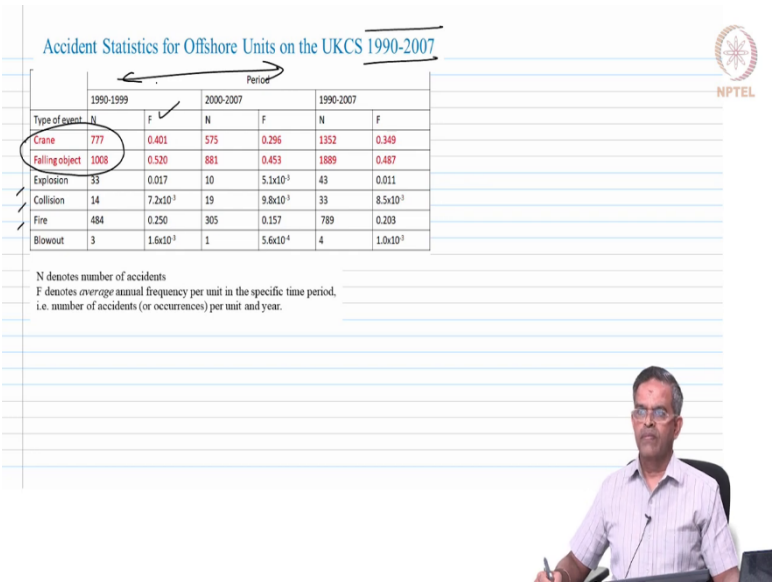

Interestingly friends, we look at the accident statistics of offshore units developed by Britain for the past 20 year's period. You can see the maximum accidents, because of drop objects have also caused fatalities and there are increased number of accidents because of crane hooks and falling objects compared to explosion, collision and fire.

See this table and this has been a consistent mark over the years. So, drop objects impact loads due to cranes are more frequent, which create accident statistics in at least offshore platforms as per the table shown on the screen.

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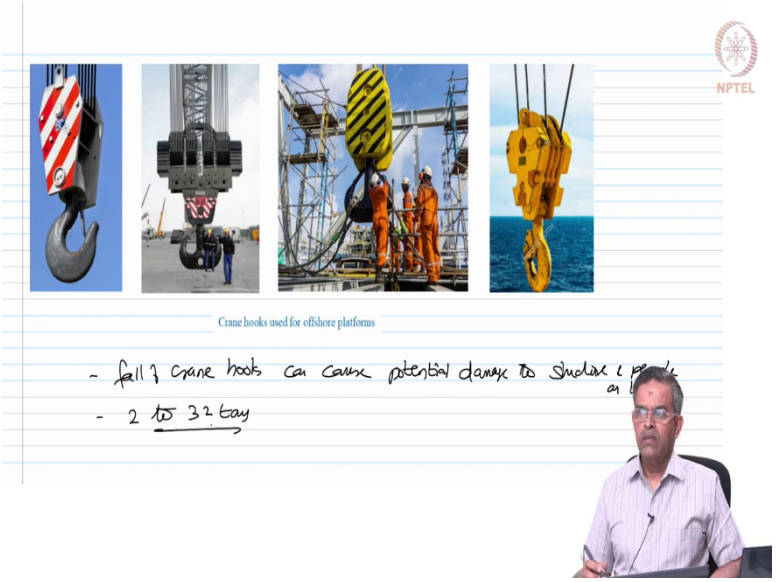

Now, the varieties of cranes being used in offshore structures are shown on the screen. So, the fall of crane hooks of these heavy mass and other objects is frequent and fall of crane hooks can cause potential damage to structure and people on board. Look at the typical crane hooks being shown on the screen. They are very massive and they vary from 2 to about 32 tons that is the range of weight these crane hooks have.

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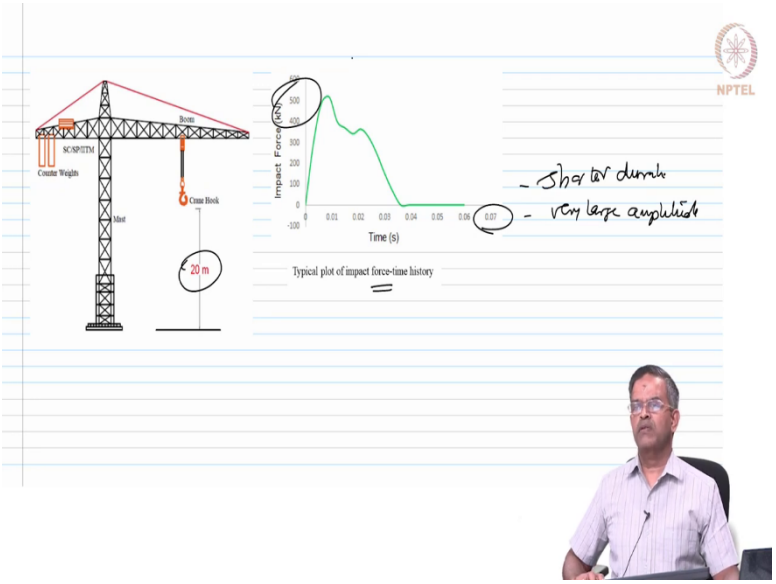

Let us pick up a specific crane hook of that order and make a model. Let us say the crane operational height ranges from 15 to 25 meters. So, let us take a 20-meter drop of the crane hook falling freely with a high velocity. Typical time history of an impact force is what you see on the screen here which has got a very shorter duration, you can see it is only about 0.07 seconds. But, a very large amplitude, very large amplitude about 50 tons etcetera. So, let us say this kind of a model is being applied for this.

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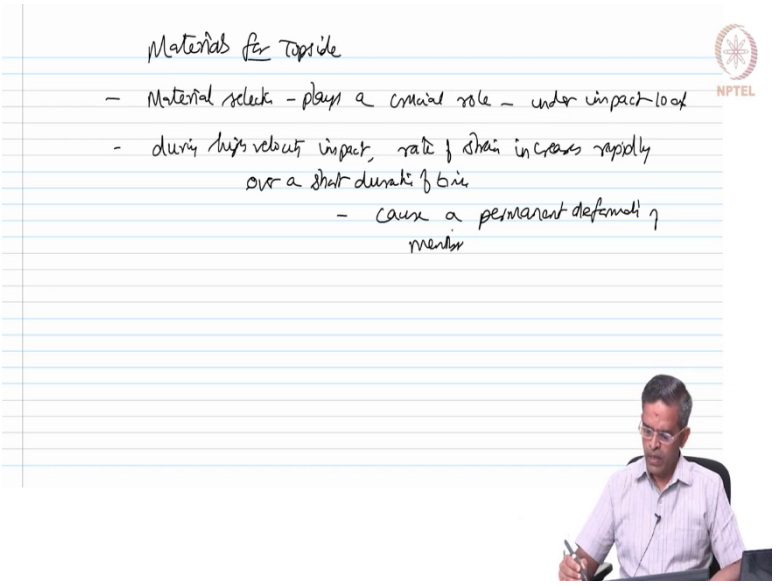

When you talk about materials, which is being used for the top side in the design, material selection plays a very crucial role particularly under impact load. During high velocity impact, the rate of strain increases rapidly over a short duration of time. This can cause a permanent deformation of member. So, the material chosen should be strong enough, should have higher toughness, higher resistance to impact loads should possess high weld ability and durability.

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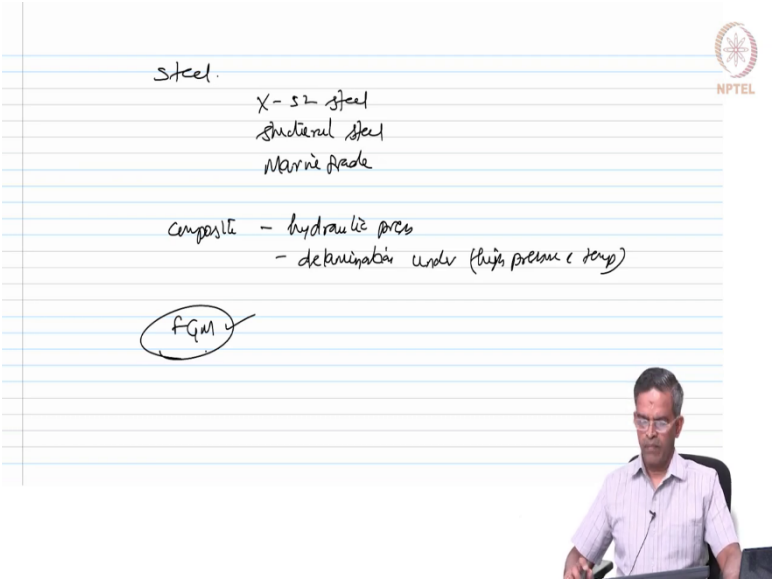

For comparison, we have taken three materials. We have taken steel which is X-52 steel which is the structural steel commonly used for offshore topside is also the marine grade steel. They have also tested with composite and FGM for comparing the performance of this topside deck. When you talk about composites and their use in offshore structures, composite plates are actually fabricated by hydraulic press.

So, they have a very serious problem of delamination under high pressure and temperature. So, new materials have been tested, we have also examined FGM. In earlier lectures of this particular course, you would know the combinations of functioning graded material and their characteristics, which has been discussed very well, in the earlier part of the lectures. Please refer them back and we have considered a specific FGM for this application for the time being.

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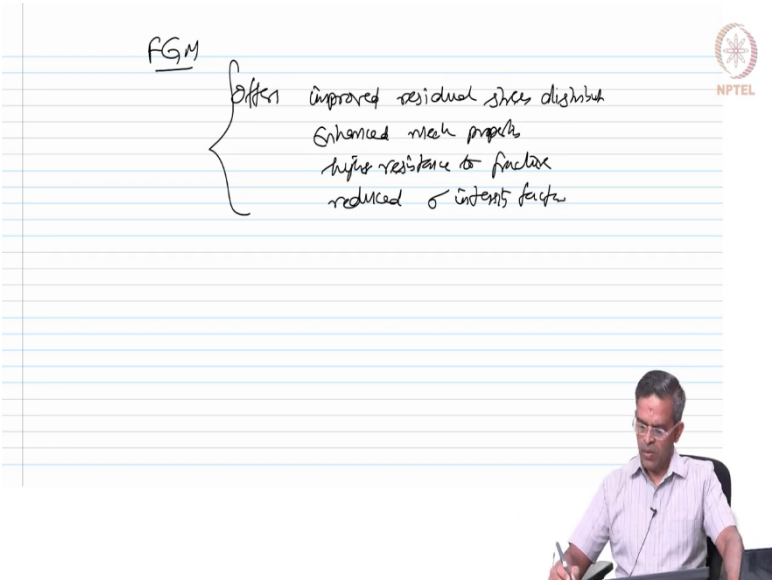

So, for our convenience let us quickly recollect that FGM offers improved residual stress distribution. It has enhanced mechanical properties. It has got higher resistance to fracture and it has got reduced stress intensity factors. So, we are not discussing about the FGM properties at this moment.

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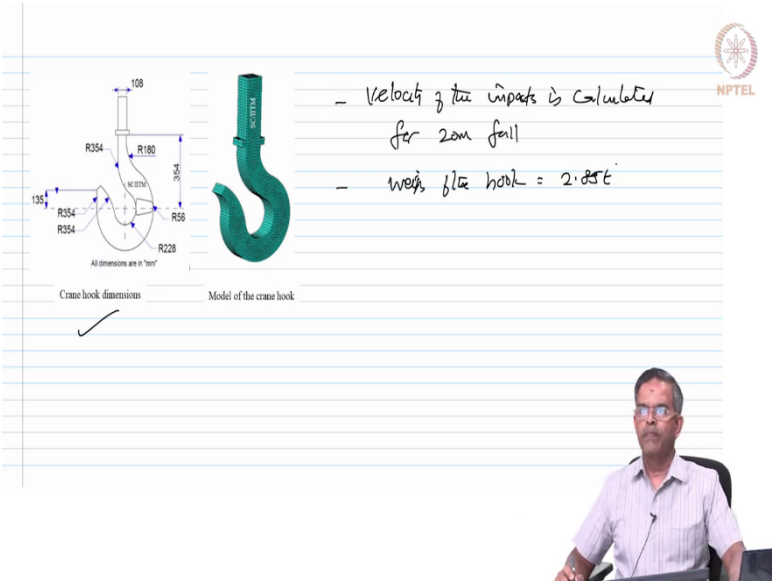

We will start directly going to the model of the crane hook. The model of the crane hook is showing on the screen whose dimensions are given here. The velocity of the impactor

considered in the analysis is calculated for 20-meter fall and the weight of the hook is taken as 2.85 tons which is subjected to the CG of this hook.

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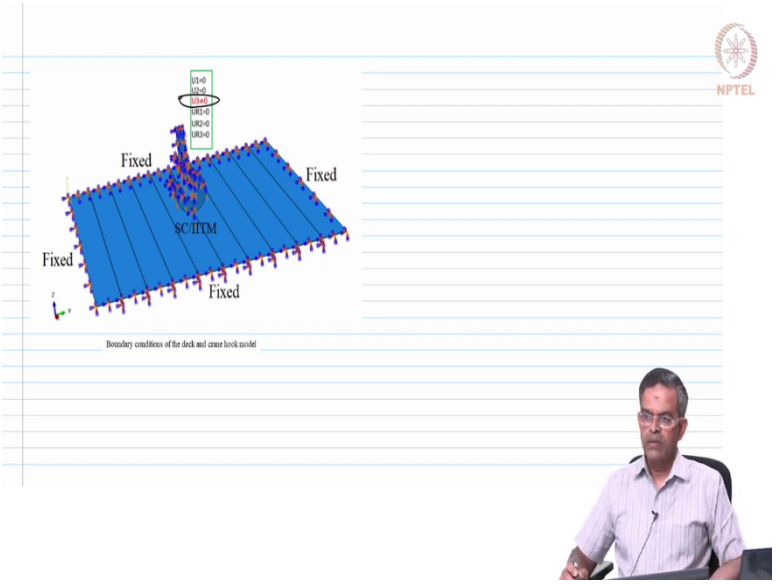

The analyst carried out in abacus and the boundary conditions for the deck and crane hook model are explained on the figure shown on the screen. The crane hook can have a rebound effect only on one direction as you see here, remaining all are restrained.

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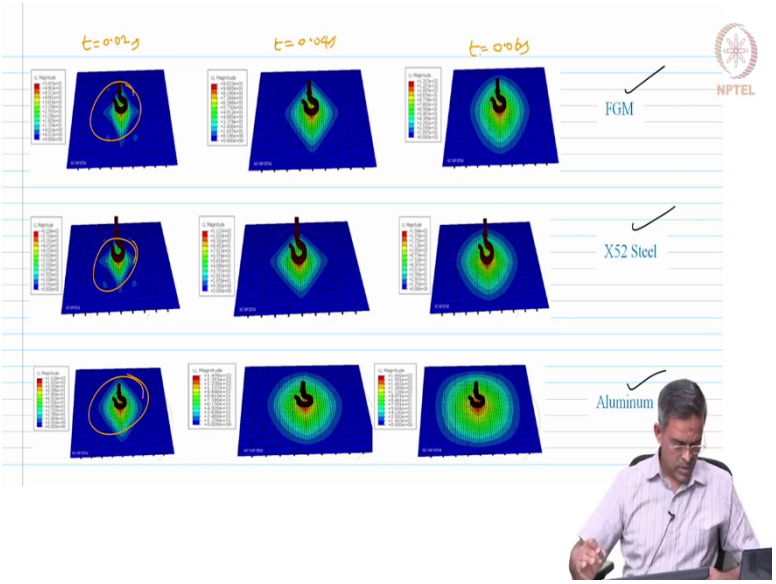

So, the deformation contour for all the three materials, I have been shown here. FGM has the stress concentration only on a smaller area compared to X-52 and aluminum. Of course, this is for t 0.02 seconds, t 0.04 seconds and this is for 0.06 seconds; over the rate of time increase of course, the impact spreads. But, even at a higher period, you will see that the stress concentration is far lesser in terms of its area of spread compared to that of X-52 and aluminum under this impact load.

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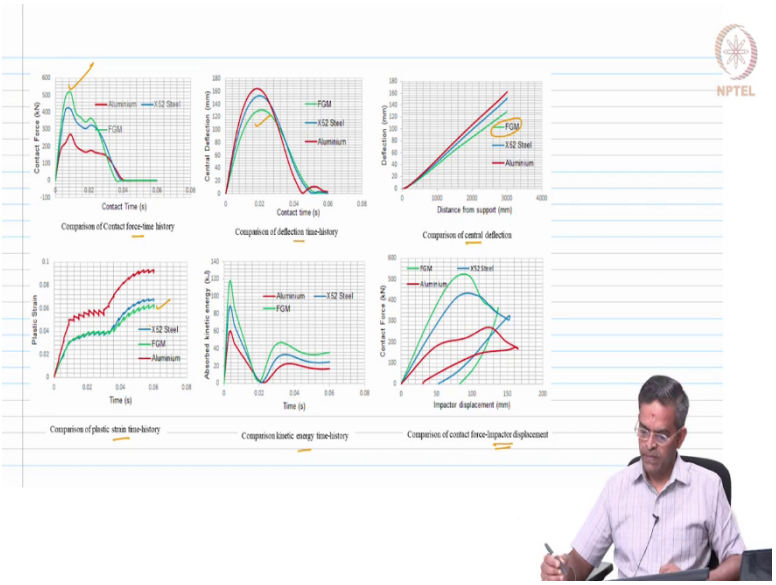

Now, the response of the deck is also plotted for contact force history, deflection time history, central deflection and comparison of plastic strain time history, kinetic energy time history and impactor displacement. In all the cases, you would very well see that FGM material performs better compared to its competitor X-52.

If you look at the central deflection of the deck which is made of FGM, it is showing far lesser values compared to the other two material taken for the study. Even the deflection time history is lesser for FGM whereas, the contact force time history is much higher for FGM. So, it has got a very good capacity of plastic strain absorption as you see here.

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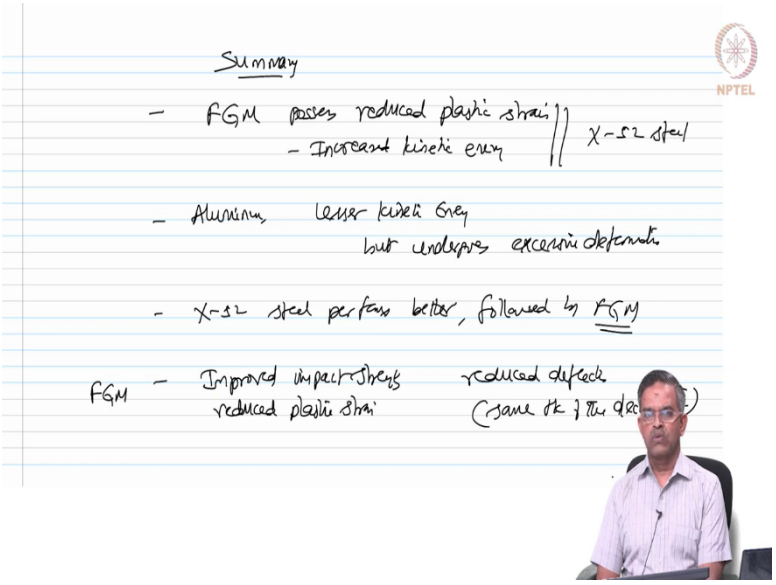

Having said this, we can now summarize that FGM possesses reduced plastic strain. It also has increased kinetic energy compared to X-52 steel. However, if you look at aluminum, it experiences lesser kinetic energy, but undergoes excessive deformation. Hence, cannot be advised for off shore deck. X-52 steel anyway performs better followed by FGM. So, FGM is far better than all the three compared materials.

So, FGM has improved impact strength, reduced plastic strain, reduced deflection, for the same thickness of the deck plate that is very important. So, there is no change in the geometry dimension of the member, only the material is being changed. So, friends a simple analysis example applied for impact loads explain how the impact analysis can be carried out using abacus, by incorporating the material characteristics of FGM and steel which are discussed in length in the previous lectures.

So, friends there are many references available for this particular course including textbooks authored by me and other leading academicians of the world. Please go through them, try to learn and create more interest towards the advanced steel design procedures, which has been discussed extensively in this course.

Thank you very much and have a good day.