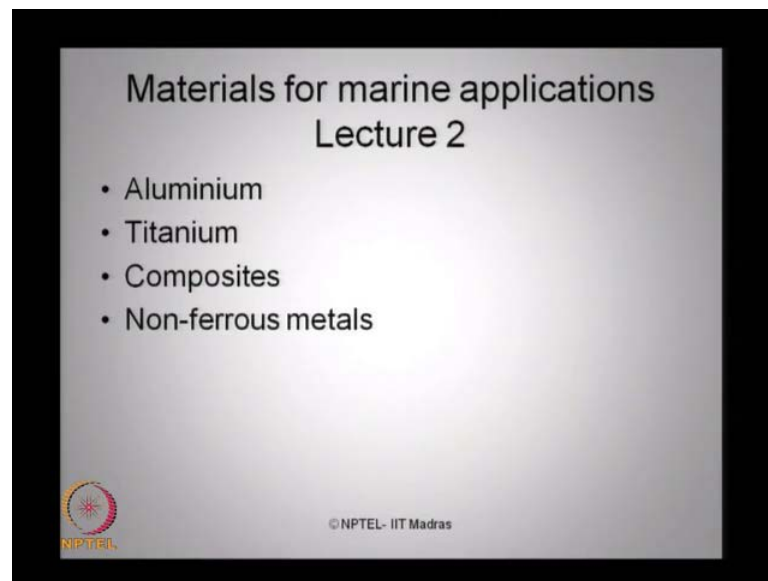


**Ocean Structures and Materials**  
**Prof. Dr. Srinivasan Chandrasekaran**  
**Department of Ocean Engineering**  
**Indian Institute of Technology, Madras**

**Module - 3**  
**Lecture - 2**  
**Introduction to Materials II**

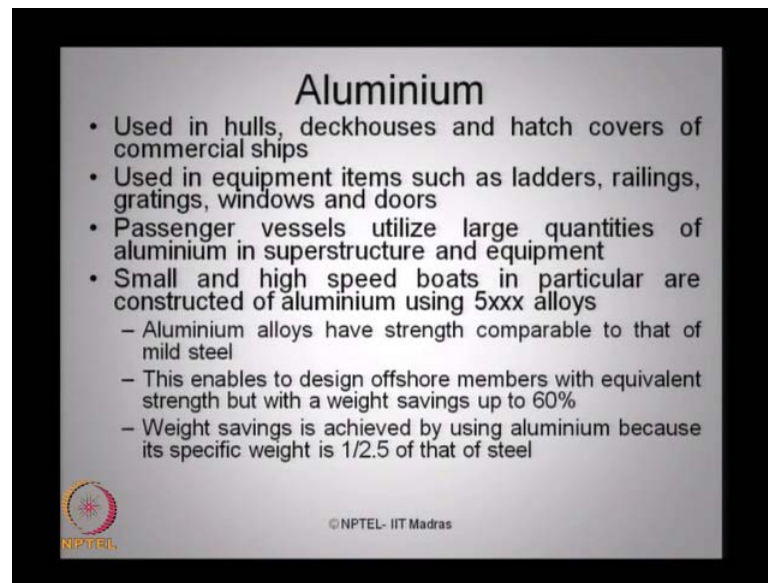
In the first lecture on the third module, we discussed about Materials that are required for marine environment, what are the special characteristics which are required to compare the material to be used in marine environment. We also discussed about the variety of specific properties which are demanded by various international codes, and we also saw the classical example of steel as a material for marine environment.

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In the present lecture will talk about other kind of materials like aluminium, titanium and composites and they suitability for marine environment and material for construction of marine structures. We will also have a very brief look out, at non-ferrous metals which can be used as construction material.

(Refer Slide Time: 01:05)



**Aluminium**

- Used in hulls, deckhouses and hatch covers of commercial ships
- Used in equipment items such as ladders, railings, gratings, windows and doors
- Passenger vessels utilize large quantities of aluminium in superstructure and equipment
- Small and high speed boats in particular are constructed of aluminium using 5xxx alloys
  - Aluminium alloys have strength comparable to that of mild steel
  - This enables to design offshore members with equivalent strength but with a weight savings up to 60%
  - Weight savings is achieved by using aluminium because its specific weight is 1/2.5 of that of steel

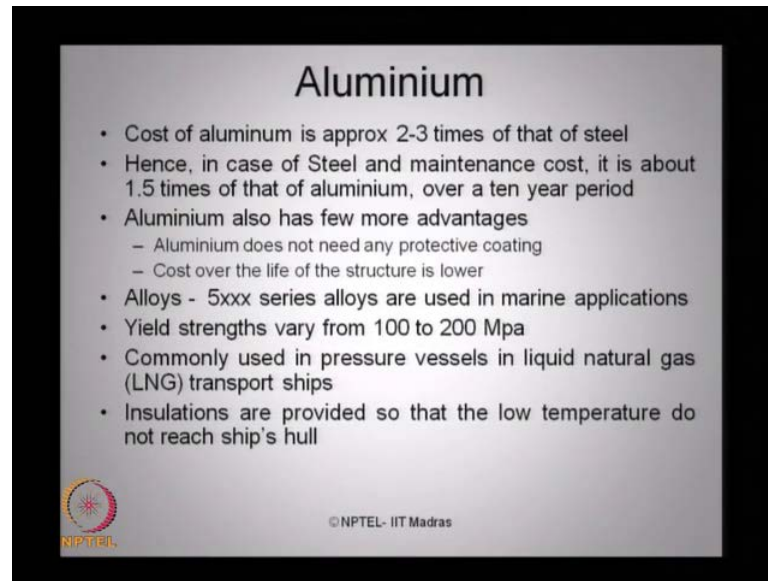
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Ladies and gentlemen, to view on the top in the list of today's lecture we will talk about aluminium, which is a very phenomenally attractive material for marine environment. There are specific reasons why aluminium is preferred as one of the construction material for ocean structures. Aluminium is used in the construction of hulls, deck houses and hatch covers of commercial ships.

It is also used in equipment items, like ladders, railings, gratings, windows and doors in the building blocks in the top side facilities of offshore platforms. The passenger vessels utilize large quantities of aluminium in super structure in equipment as well. Small and high speed boats in particular are constructed of aluminium using five x x x alloy a specific pattern of an alloy of aluminium. Now, aluminium alloys have several advantages over other material.

Aluminium alloys have strength comparable to that of mild steel, this enables to design the offshore members with equivalent strength as that of steel, but to the weight saving up to as high as 60 percent weight saving is achieved actually because aluminium has a specific weight which is 1 by 2.5 of that of steel. Because, of this phenomenal advantage of aluminium, aluminium can excered the same strength. So, that of the mild steel at the same time the weight is highly low as compare to that of steel.

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### Aluminium

- Cost of aluminum is approx 2-3 times of that of steel
- Hence, in case of Steel and maintenance cost, it is about 1.5 times of that of aluminium, over a ten year period
- Aluminium also has few more advantages
  - Aluminium does not need any protective coating
  - Cost over the life of the structure is lower
- Alloys - 5xxx series alloys are used in marine applications
- Yield strengths vary from 100 to 200 Mpa
- Commonly used in pressure vessels in liquid natural gas (LNG) transport ships
- Insulations are provided so that the low temperature do not reach ship's hull

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The cost of aluminium approximately is about 2 to 3 times of that of steel use for offshore construction; however, in case of steel and aluminium maintenance cost put together, if you add steel and the maintenance cost of steel it is about 1 and half times of that of aluminium. Because, steel has got a phenomenal expenditure towards it is constant maintenance. If you look at this statistics over a 10 year period of time initially investment of aluminium as a member, structural member may be marginally high.

But, if you look at the total cost of maintenance as per as initial investment steel will cost you about 50 percent more than that of aluminium over a span of service life about 10 years; however, aluminium cannot be used as a construction material for offshore structures for all kinds of members there are limitations will discuss them in the successive slides.

Aluminium has few more salient advantages, aluminium extra ordinarily advantages. Because, it does not need any protective coating as that of steel, the cost over life of the structure is lower because it is as good as free maintenance. Alloys of five x x x series of aluminium are essentially, used very widely in marine applications. Yield strength of this material varies in the range of 100 to 200 mega Pascal. So, aluminium is seen as one of the very alternative as an advantage material with respect to steel.

And aluminium has lower specific weight compared to that of steel therefore, the overall weight of this construction material and used in offshore structure will be phenomenally

low which is claimed as one of the important advantage. Another advantage in the construction point of view is that aluminium is more or less free maintenance material whereas steel need to be maintained constantly, because steel gets corroded in marine environment.

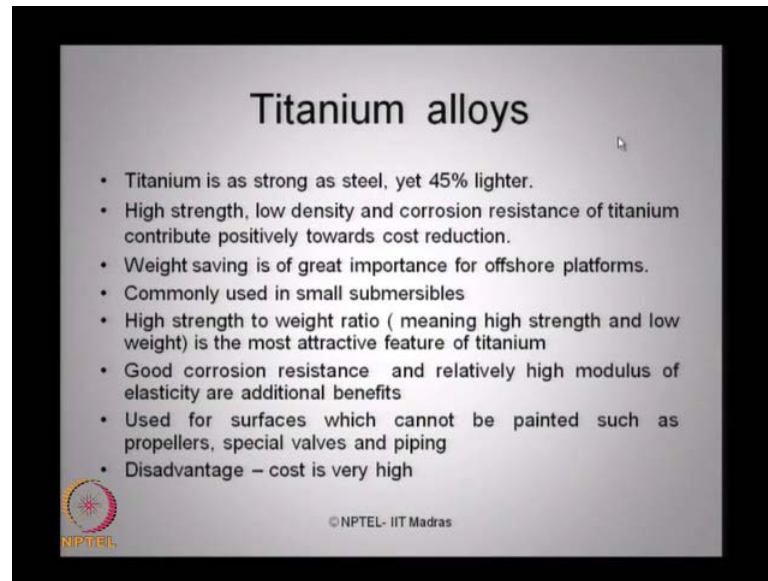
Commonly used are in pressure vessels basically, where L N G transport ships are been deployed in offshore. Insulations are also provided with the aluminium. So, that low temperature does not reach the ship's hull.

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The next competitive material in the line which again competes with the aluminium and that of steel, as a construction material for offshore and marine application is titanium.

(Refer Slide Time: 05:27)



The slide is titled "Titanium alloys" and contains a bulleted list of characteristics. The text is as follows:

- Titanium is as strong as steel, yet 45% lighter.
- High strength, low density and corrosion resistance of titanium contribute positively towards cost reduction.
- Weight saving is of great importance for offshore platforms.
- Commonly used in small submersibles
- High strength to weight ratio ( meaning high strength and low weight) is the most attractive feature of titanium
- Good corrosion resistance and relatively high modulus of elasticity are additional benefits
- Used for surfaces which cannot be painted such as propellers, special valves and piping
- Disadvantage – cost is very high

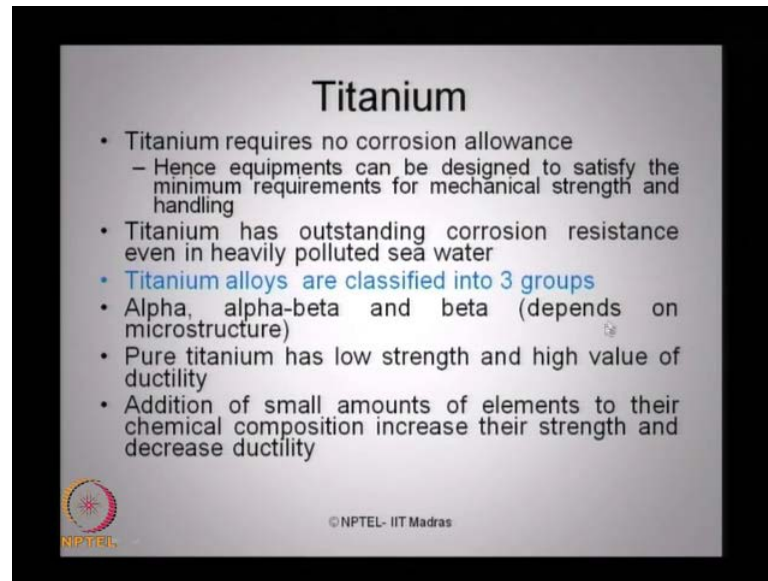
At the bottom left of the slide is the NPTEL logo, and at the bottom center is the text "© NPTEL- IIT Madras".

Titanium alloys are increasingly, commonly being used, now in offshore application. Titanium, ladies and gentlemen is as strong as steel, but yet about 50 percent lighter. High strength, low density and corrosion resistance of titanium alloys contribute positively towards the cost reduction and become attractive for this material to be recommended for marine applications. Weight saving is one of the important and great advantage, if we talk about design of offshore platforms.

And aluminium is commonly used in small semi- submersible platforms. High strength to weight ratio that is, high strength at lower weight is a most attractive feature of titanium. Good corrosion resistance and relatively high modulus elasticity are considered to be additional benefits of titanium alloys. Used for surfaces which cannot be painted such as, propellers, special valves and piping. Ladies and gentlemen, possibly titanium is the only material which can be suiting all these requirements as you see in the slide here.

It is got a very serious disadvantage, initial cost of investment of this material as a construction material for offshore platforms is phenomenally high.

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The slide is titled "Titanium" and contains the following text:

- Titanium requires no corrosion allowance
  - Hence equipments can be designed to satisfy the minimum requirements for mechanical strength and handling
- Titanium has outstanding corrosion resistance even in heavily polluted sea water
- Titanium alloys are classified into 3 groups
- Alpha, alpha-beta and beta (depends on microstructure)
- Pure titanium has low strength and high value of ductility
- Addition of small amounts of elements to their chemical composition increase their strength and decrease ductility

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Titanium actually requires no corrosion allowance at all. Hence, equipments can be designed to satisfy the minimum requirements for mechanical strength and handling as well. Titanium is an outstanding corrosion resistance even in heavily polluted sea waters. Titanium alloys can be classified in to 3 groups, as you see, now alpha, beta and beta. This grouping of titanium alloys actually, depends on the microstructure of this material.

Pure titanium has lower strength and high value of ductility, this is considered as an disadvantage therefore, this microstructure has been altered by adding small amount of elements to their chemical composition, which increases strength as well as decreases its ductility marginally.

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**Why is Titanium used in Offshore Applications?**

- Increase in disruptive failures of stainless steel and copper based alloys (safety concern)
- titanium continues to be available at competitive and relatively stable prices
- Growth of fabrication experience (pipes, fittings and systems)
- Improved availability of information to design engineers of the useful combination of properties of titanium
- In flowing or static sea water at temperatures up to 130°C, titanium surfaces are immune to corrosion
  - Other metals and alloys corrode significantly at this environment.
- Titanium is immune to crevice corrosion up to at least 70°C in sea water
  - For example, some stainless steels are only limited to 10°C.

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Why titanium is used in offshore application. It is a very interesting question; there are specific reasons for this. Increase in disruptive failures of stainless steel and copper based alloys force a very serious question to offshore application in the safety point of view. So, in safety concern titanium is upcoming replaced material in comparison to stainless steel and copper alloys, in particular for offshore applications. Titanium continuous to be available at a competitive price, this is one of the important advantage what titanium claims in the recent paths.

When titanium was launched as a construction alternative material for marine application the introductory cost of this material was phenomenally high. So, people were not comfortable to invest on a high range of material for a marine application whose service life is highly limited. So, the initial investment of offshore applications went high when titanium was thought to replace construction material like steel and copper alloys.

But, in the recent past titanium was available at very competitive and most importantly a stable price in the market. So, there is no fluctuation of material cost as for as titanium is concern in the market. The great advantage what titanium now, claims is growth of fabrication experience, people have in train skilled labels are available techniques have been imparted, impartially in a different methodologies where, fabrication of titanium alloys can be comfortably done with recent advance technologies for piping's fittings and systems.

So, ladies and gentlemen, availability of titanium at a stable price, a relatively a competitive price, I will not say it is cheaper; I am agreeing that titanium is an expensive material compared to steel. But it is competitive because it is having other parallel advantages -it is phenomenally high corrosion resistant. So, the maintenance cost practically become 0 when use titanium or for example, aluminium. Of course, a strength of titanium can be as high as 400 mega Pascal which is equal in to steel.

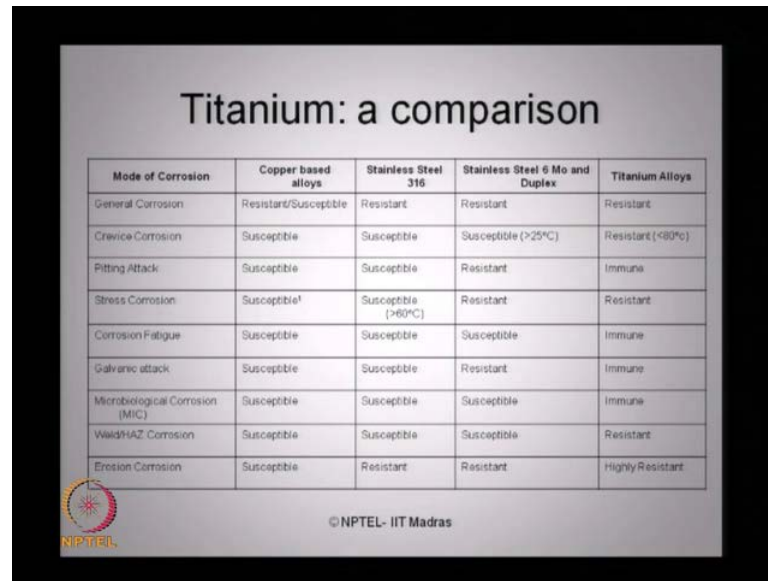
So, we have a material here which replaces steel at an initial investment higher cost marginally, but at a stable price. And in phenomenal methods of fabrication techniques are available therefore, for piping, fittings and systems people, now prefer a titanium as a very important alternate material in offshore applications. Improved availability of information to a design engineer of useful combination of property of titanium is, now available in the recent literature.

In flowing or static condition at temperatures up to 130 degree centigrade titanium surfaces are immune to corrosion. It is a very important and attractive property what titanium basically, titanium is the only material which possesses characteristics as of now. At a very high temperature of 130 degree Celsius in a marine environment titanium remains as corrosion free, on the other hand if you look at steel under this case another metals and alloys corrode terribly at this environment.

Titanium is immune to what we call crevice corrosion up to at least 70 degree Celsius in sea water. If you look at a comparative study of this specific crevice corrosion characteristics either of steel stainless steel possesses this characteristic only if to temperature of about 10 to 12 degree Celsius. So, titanium has a catabolic edge of advantage over stainless steel has a material in terms of crevice corrosion resistance. And it possesses advantage over other materials and alloys because it remains immune to corrosion even at a very high temperature of 130 degree Celsius.



(Refer Slide Time: 12:11)



The slide displays a table titled "Titanium: a comparison" comparing the corrosion resistance of four materials: Copper based alloys, Stainless Steel 316, Stainless Steel 6 Mo and Duplex, and Titanium Alloys. The table lists ten modes of corrosion and their susceptibility for each material.

Mode of Corrosion	Copper based alloys	Stainless Steel 316	Stainless Steel 6 Mo and Duplex	Titanium Alloys
General Corrosion	Resistant/Susceptible	Resistant	Resistant	Resistant
Crevice Corrosion	Susceptible	Susceptible	Susceptible (>25°C)	Resistant (<80°C)
Pitting Attack	Susceptible	Susceptible	Resistant	Immune
Stress Corrosion	Susceptible <sup>1</sup>	Susceptible (>60°C)	Resistant	Resistant
Corrosion Fatigue	Susceptible	Susceptible	Susceptible	Immune
Galvanic attack	Susceptible	Susceptible	Resistant	Immune
Microbiological Corrosion (MIC)	Susceptible	Susceptible	Susceptible	Immune
WeldHAZ Corrosion	Susceptible	Susceptible	Susceptible	Resistant
Erosion Corrosion	Susceptible	Resistant	Resistant	Highly Resistant

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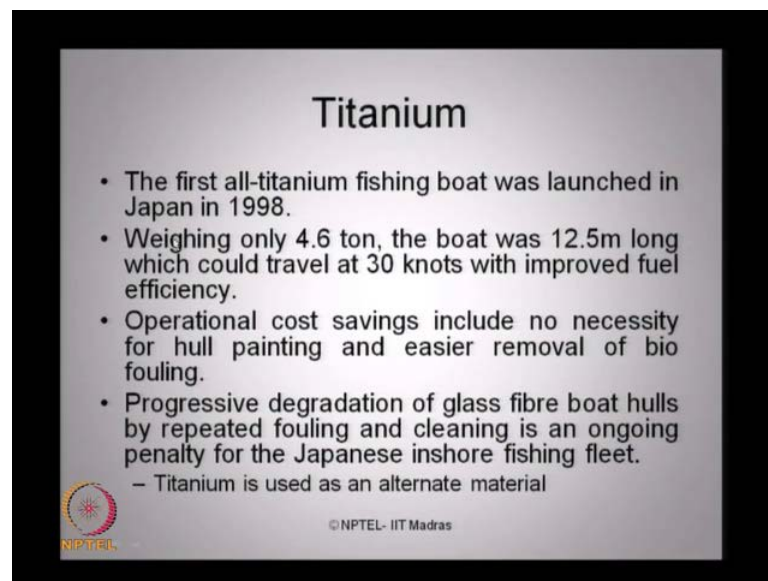
Ladies and gentlemen, here is the table which compares titanium with other kinds of material. It is not deliberately shown to you, so that titanium is the only material which is promoted and projected for offshore application, but people do not use titanium because of fear and because of high increase in cost. But it is not true the recent paths, look at the table which gives you comparative advantage of titanium alloy with respect to stainless steel which is duplex 6 mono and stainless steel 360 and copper based alloys.

If you look at the modes of corrosion, general corrosion you will see all of them all are resistant except the copper base alloy which can be susceptible. If you look at the corrosion crevice corrosion copper base alloys and stainless steel 360 are highly susceptible. Stainless steel duplex also, susceptible if increase temperature beyond 25 degree whereas, titanium alloys remain resistant up to a temperature about 80 degree Celsius;. if you look at pitting a tap which is a very common disturbing phenomenon of members in marine application.

Copper based alloys and stainless steel 316 remains susceptible whereas, titanium alloys are highly immune to this. If you look at this stress concentration all of them are almost susceptible except the titanium alloy which remains as resistance to stress corrosion. So, ladies and gentlemen, look at the modes of corrosion and you will find titanium alloys almost fulfil all of them, except very few whereas, other kinds of material do not qualify in majority of the cases.

So, titanium has a very clear edge as a construction material for marine application. The only demerits you see now, is a increased initial investment terms of it is cost. Naturally, I strongly agree titanium and aluminium are more expensive than steel if you look at the initial cost alone and if you look at the maintenance part together for a period of service lane of 10 years. You will find ladies and gentlemen, titanium and aluminium can be a competitive affordable, replaceable material compared to that of steel in marine structures.

(Refer Slide Time: 14:29)



The slide is titled "Titanium" in a bold, black font. Below the title is a list of four bullet points. The first bullet point states that the first all-titanium fishing boat was launched in Japan in 1998. The second bullet point describes the boat's weight (4.6 tons) and length (12.5m), noting its speed (30 knots) and improved fuel efficiency. The third bullet point lists operational cost savings, specifically the lack of need for hull painting and easier removal of bio fouling. The fourth bullet point discusses the degradation of glass fibre boat hulls due to repeated fouling and cleaning, which is an ongoing penalty for the Japanese inshore fishing fleet. A sub-bullet point indicates that titanium is used as an alternate material. In the bottom left corner, there is a circular logo with a red and yellow design and the text "NPTEL". In the bottom right corner, there is a small copyright notice: "© NPTEL- IIT Madras".

- The first all-titanium fishing boat was launched in Japan in 1998.
- Weighing only 4.6 ton, the boat was 12.5m long which could travel at 30 knots with improved fuel efficiency.
- Operational cost savings include no necessity for hull painting and easier removal of bio fouling.
- Progressive degradation of glass fibre boat hulls by repeated fouling and cleaning is an ongoing penalty for the Japanese inshore fishing fleet.
  - Titanium is used as an alternate material

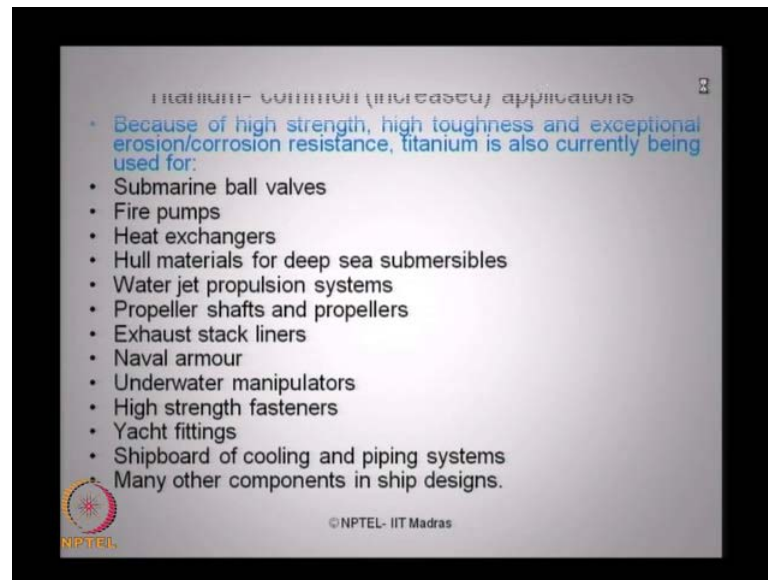
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The first all titanium fishing boat was launched in Japan in the year 1998. Weighing only just 4.6 tons the boat was about 12.5 meter long which could travel at a phenomenal speed of 30 knots of course, there has been some mechanism diverge the fuel efficiency was improved in this boat to attain the speed. Operational cost savings include no necessity for hull painting and easier removal of bio fouling.

Ladies and gentlemen, focus on one important environmental impact of material being used and recommended for offshore application you will see bio fouling is a more attractive area where, people started paying more attention to material degradation processes and their counter effects on the bio organisms in the sea water. So, titanium still remains advantages because it has got lot of phenomenal characteristics which does not affect if it is degraded to cause a bio fouling in sea water.

Progressive degradation of glass fibre boat hulls by repeated fouling and cleaning is an on-going penalty for Japanese inshore fishing fleet therefore, titanium has been, now phenomenally used increasingly as an alternate material for small vessel constructions and ship boat building in countries like Japan.

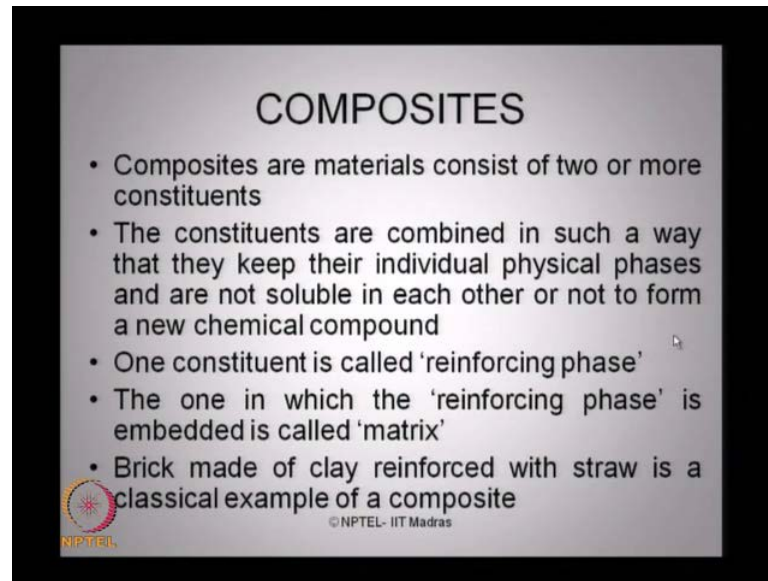
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Titanium also has become common which has increased in the recent pasts in applications in marine environment. The reasons are the following because; of it is very high strength high toughness and exceptional and phenomenal erosion or corrosion resistant, titanium is currently being used in majority of offshore applications. They are being used as sub marine ball valves, higher pumps, heat exchangers, hull material for deep sea submersibles, water jet propulsion systems, propeller shafts and propellers, exhaust stack liners, navel armours, under water manipulators, high strength fasteners, yacht fittings, ship board of cooling and piping systems, many other components in ship design.

You will see titanium has got very increased application in marine environment in the recent paths.

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The slide is titled "COMPOSITES" in a large, bold, black font at the top center. Below the title is a bulleted list of five points. The first point states that composites consist of two or more constituents. The second point explains that these constituents are combined in a way that they retain their individual physical phases and do not form a new chemical compound. The third point identifies one constituent as the 'reinforcing phase'. The fourth point identifies the matrix as the phase in which the reinforcing phase is embedded. The fifth point provides a classical example: a brick made of clay reinforced with straw. In the bottom left corner of the slide, there is a small circular logo with a star-like pattern and the text "NPTEL" below it. In the bottom right corner, there is a small copyright notice: "© NPTEL- IIT Madras".

## COMPOSITES

- Composites are materials consist of two or more constituents
- The constituents are combined in such a way that they keep their individual physical phases and are not soluble in each other or not to form a new chemical compound
- One constituent is called 'reinforcing phase'
- The one in which the 'reinforcing phase' is embedded is called 'matrix'
- Brick made of clay reinforced with straw is a classical example of a composite

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The other competitive material which race with aluminium and titanium in today's lecture are composites. Now, what are composites how do they have advantages, how advantageous have been composites with respect to that of aluminium and titanium and against steel. Let's see the now, down the line. Composites are materials, which consists of two or more constituents. The constituents are combined in such a manner that they keep the individual and physical phases and are not soluble in each other not to form a new chemical compound.

One constituent is what we called rein forcing phase, the other one is a matrix phase the one in which the rein forcing phase is embedded is what we called matrix. Brick made of clay rein force with straw is a classic example of a composite.

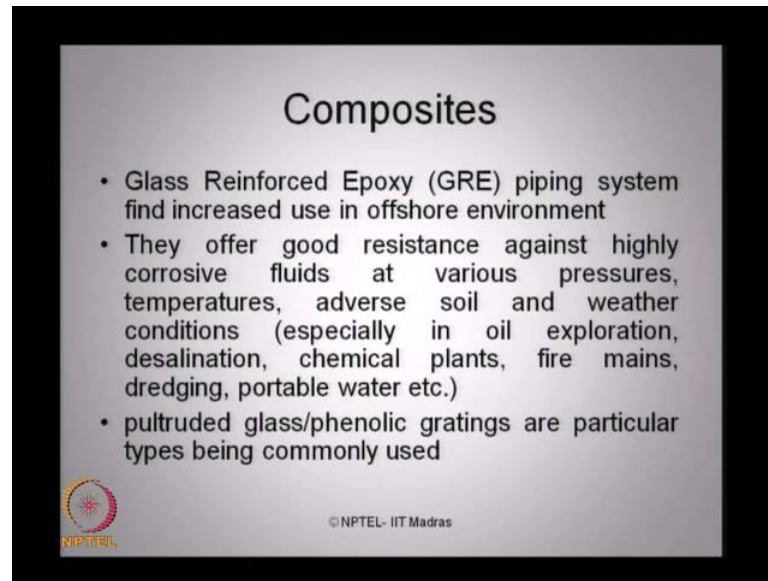
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Let us quickly see, how composites are classified. Composites are essentially classified based on the geometry of the reinforcing phase. Particulate Reinforced Composites, which you call them as PRC. Flake Reinforced Composite FRC. Fibre Reinforced Composite (FRC). Continuous fibre, short fibre and whiskers can be again a sub classification in fibre, reinforced composites. It is also classified based on the type of matrices what we use.

Polymer matrix composite, can be metal matrix composite, can be ceramic matrix composite, can be carbon fibre or carbon acetous matrix composite, can be fibre reinforced polymeric composite, it can be particulate reinforced metal matrix composites. It can be a hybrid variety which uses multiple reinforcements and matrices for example, carbon fibre and glass fibre in epoxy matrix is a hybrid variety of example of a composite.

(Refer Slide Time: 19:02)



The slide is titled "Composites" and contains three bullet points. The first bullet point states that Glass Reinforced Epoxy (GRE) piping systems are finding increased use in offshore environments. The second bullet point notes that these systems offer good resistance against highly corrosive fluids at various pressures, temperatures, and adverse soil and weather conditions, with examples including oil exploration, desalination, chemical plants, fire mains, dredging, and portable water. The third bullet point mentions that pultruded glass/phenolic gratings are particular types being commonly used. In the bottom left corner, there is a small circular logo with a star and the text "NPTEL". In the bottom right corner, the text "© NPTEL- IIT Madras" is visible.

### Composites

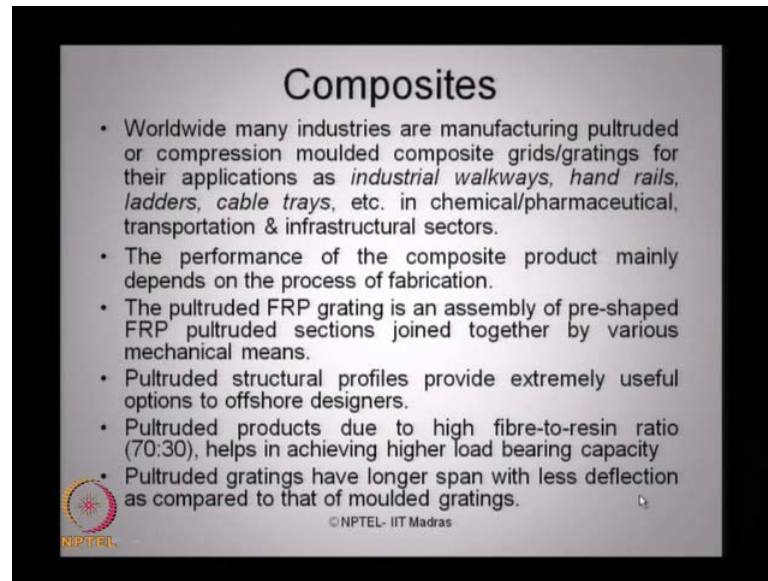
- Glass Reinforced Epoxy (GRE) piping system find increased use in offshore environment
- They offer good resistance against highly corrosive fluids at various pressures, temperatures, adverse soil and weather conditions (especially in oil exploration, desalination, chemical plants, fire mains, dredging, portable water etc.)
- pultruded glass/phenolic gratings are particular types being commonly used

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Now, Glass Reinforced Epoxy for example, G R E which is seen in the literature has found of a phenomenal application the piping systems, in offshore environment. They offer good resistance against highly corrosive fluids because as we understand the operational temperature and pressure in case of explanation of oil in the subsea or entirely in a very high range. So, I need a pipe line, I need a stack or I need a raiser which can be immune to this kind of highly corrosive fluids at very high temperature at various pressures, adverse soil and weather effects etcetera.


So, G R E which is a glass rein forced epoxy composite has been fine an increasing application in the piping systems which is majority use in offshore environment because they have got very good fire resistant, chemical resistant, etcetera. Pultruded glass or phenolic gratings are generally particular type of composites which have been commonly used in offshore piping systems.

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**Composites**

- Worldwide many industries are manufacturing pultruded or compression moulded composite grids/gratings for their applications as *industrial walkways, hand rails, ladders, cable trays*, etc. in chemical/pharmaceutical, transportation & infrastructural sectors.
- The performance of the composite product mainly depends on the process of fabrication.
- The pultruded FRP grating is an assembly of pre-shaped FRP pultruded sections joined together by various mechanical means.
- Pultruded structural profiles provide extremely useful options to offshore designers.
- Pultruded products due to high fibre-to-resin ratio (70:30), helps in achieving higher load bearing capacity
- Pultruded gratings have longer span with less deflection as compared to that of moulded gratings.

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Worldwide many industries are now, manufacturing pultruded or compression moulded composite grids or gratings which have got very wide variety of applications industry. Ladies and gentlemen in day to day life you must having seeing this in wide applications for example, industrial walkways, sky walks, hand rails, ladders, cable trays, etcetera and chemical and pharmaceutical companies which is got highly corrosive environment have started using G R E composites further applications.

The performance of composite product mainly depends on how you fabricate it. The pultruded F R P grating is an assembly of pre shaped F R P pultruded sections joined together by various mechanical means. So, remember ladies and gentlemen, the characteristic of a composite can be advantageous and modified depending up on the process of fabrication. So, one such interesting fabrication methodology which is commonly used in for material, as offshore application, is pultruded F R P grating.

Pultruded structural profiles provide extremely useful options to offshore designers for materials and members in offshore construction. Pultruded products have high fibre to resin ratio. This ratio in the literature is as high as 70 to 130, helps in achieving the higher load bearing capacity. So, the properties and the characteristics and the methodology of fabrication are suitably modified engineering design. Thus load bearing capacity of a pultruded product of a composite can be equivalently good as that of any other material which is being use for member construction of offshore industry.

Pultruded gratings have longer span with less deflection. So, that is another advantage when you are going to use them for decks in the top side. If you compare this with the moulded grating of that of composites itself, pultruded grating still have an edge over the moulded gratings because they can sustain longer span with lesser deflection which is one of the important criteria for the top side in offshore structures.

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The pultruded grating panels can be easily cut; therefore, fabrication becomes simple and can be modified as per your dimension requirements. Therefore, fabrication construction easiness, dismantle and transportation, becomes as simple; so people get attracted towards the use of pultruded grating composites for top side construction in offshore industry. In recent times, phenolic gratings are also be extensively use in offshore application where fire safety has become important.

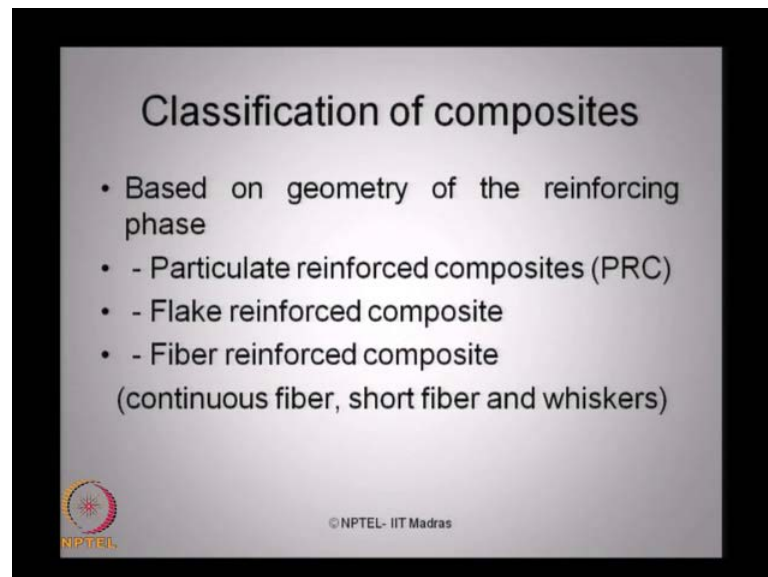
As we understand, ladies and gentlemen, you must have heard and learnt many accidents takes place commonly, in offshore industry top sides, but not in the recent paths people are been. Doing intelligent designs in the recent paths. So, catastropic extense of because of fire are greatly avoided; however, there has been instances naturally in offshore industry where fire accidents took place. So, now, in the recent paths people have started replacing some of the material and as phenolic grating material which is got a very high resistance for fire protection.



The main advantage of a phenolic grating lies not only in their performance during fire, but most importantly the ability to retain significant level of functionality even expose to fire including low smoke and low emission. Ladies and gentlemen you must understand in case of many fire release models, emission control model. It is fire which is less hazardous, but the smoke is more hazardous than fire, people, actually, become, panic only because of the dark thick smoke and smoke not because of fire.

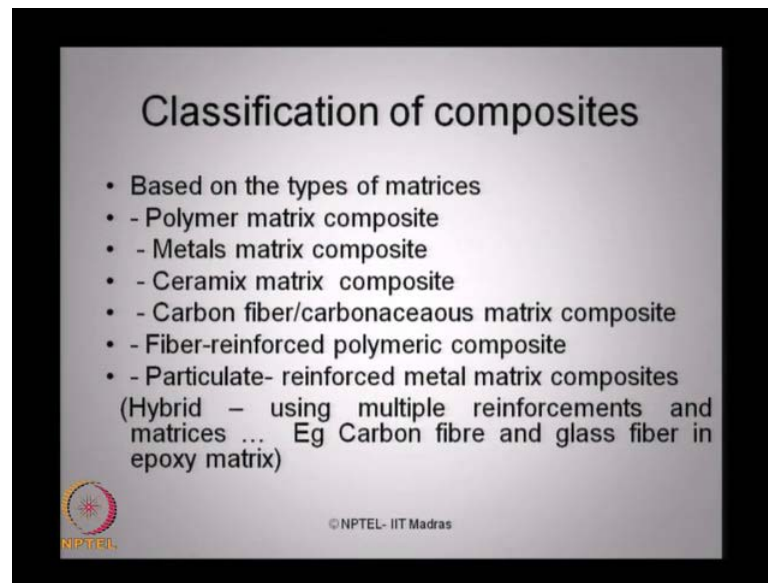
So, you see phenolic gratings have an advantage of having good fire resistant there expose to fire for a larger period they got a very low smoke and emission.

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That is a very important advantage as phenolic gratings are concern. Let us quickly look at the classification of composites, based on geometry of reinforcing phase I can say particulate reinforced composites, flake reinforced composites, fibre reinforced composites, which is having continuous fibre short fibre and whiskers.


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**Classification of composites**

- Based on the types of matrices
- - Polymer matrix composite
- - Metals matrix composite
- - Ceramix matrix composite
- - Carbon fiber/carbonaceous matrix composite
- - Fiber-reinforced polymeric composite
- - Particulate- reinforced metal matrix composites

(Hybrid – using multiple reinforcements and matrices ... Eg Carbon fibre and glass fiber in epoxy matrix)

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Based on the type of matrices, we can have a polymer matrix composite, metals matrix composite, ceramic matrix composite, and carbon fibre matrix composite and fibre reinforce polymeric composite and particulate reinforce metal matrix composites,. But cannot say have an hybrid variety as we discussed in the previous live.

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**Composites**

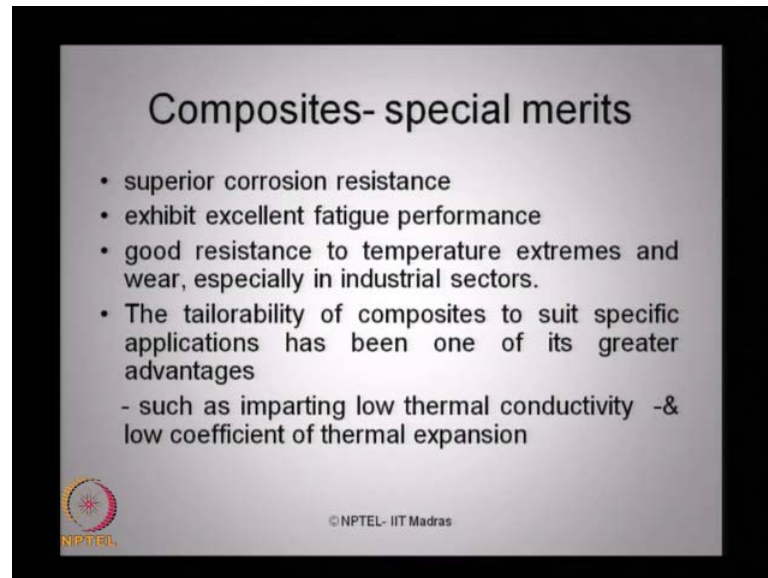
- Meet diverse design requirements and exhibit high strength-to-weight ratio compared to conventional materials.
- Proved to be a worthy alternative to other traditional materials even in the high-pressure & aggressive environmental situations.

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Composites actually meet diverse design requirements. They also exhibit high strength to weight ratio, that is at a lower weight material gives you higher strength. So, they meet highest strength to weight ratio compared with that of other conventional materials

which means to attractive for offshore application. Composites in the recent paths proved to be worthy alternative to other traditional materials even in high pressure and aggressive environmental situations.


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Composites are special merits, ladies and gentlemen, superior corrosion resistance, exhibition of excellent fatigue performance, good resistance to temperature extremes and where especially in industrial sectors, the tailor ability that is the constructability of composites to suit specific applications has been one of the major advantage of composites. Such as, imparting low thermal conductivity, low coefficient thermal expansion.

So, the structural properties and the mechanical characteristics of composites can be easily altered by, method of manufacturing, method of fabrication, so, that you can make it as low thermal conductive and low having low coefficient thermal expansion as well. So, this kind of terribility makes composite as an advantage of material for off offshore materials. In addition they were very high axial strength and stiffness as well.

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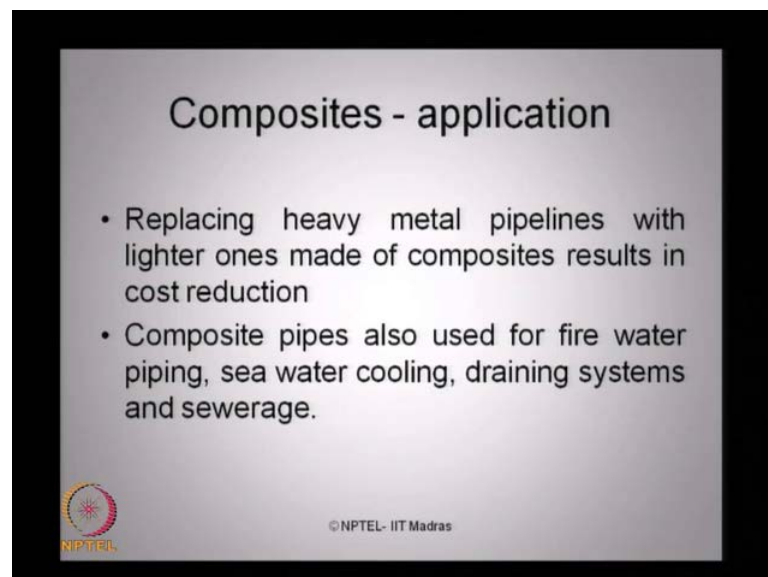
## Composites

- Extensive applications are seen in the oil & gas industry since last two decades.
- Significant advances have been made in the areas of composite pipe work and fluid handling.
- High cost to replace steel piping in retrofit applications prompted to use composites
- increased longevity in new construction is an added advantage

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Extensive applications are seen in oil and gas industry in the recent paths in 50 years. Significant advantages and advance have been made in the areas of composite pipe work and fluid handling. High cost to replace steel piping in retrofitting them prompted people to use composites. Increase longevity a new construction is an added advantage which is gain by use of composites in construction material for marine applications.

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## Composites - application

- Replacing heavy metal pipelines with lighter ones made of composites results in cost reduction
- Composite pipes also used for fire water piping, sea water cooling, draining systems and sewerage.

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Composites, ladies and gentlemen, have now replaced heavy metal pipelines with lighter ones. Because, it is a phenomenal decrease in cost, composite pipes are also used for fire water piping, sea water cooling, drainage systems and sewerage applications.

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Composites also have many advantages and applications. The cost advantage of composite products are much greater when they are replaced by expensive corrosion resistant metals such as, copper nickel alloy, titanium et cetera. Their resistance to corrosion helps in improving reliability and safety and also lead to lower life cycle cost. It is a very important factor which is an important assessment in construction management technique of offshore industry.

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With technology innovations and developments and processing and products, composites become an attractive candidate for many applications I will list few here, top side application in offshore platforms, down hole tubing in the subsea. We have discussed this in module 1 in one of the lectures. And many other similar applications where composites have become very attractive in the recent paths in offshore industry.

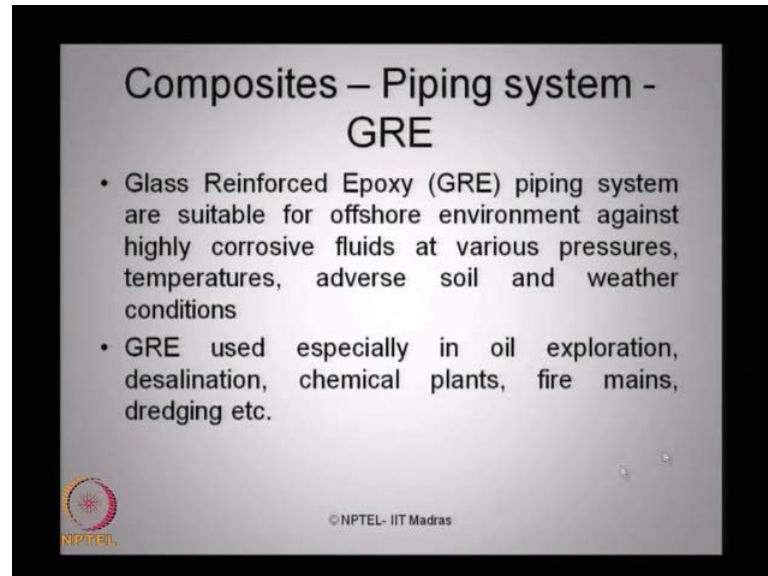
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The selection of suitable resin plays a very important role for imparting the durability characteristics to composites when expose to aqueous fluids. The important issues

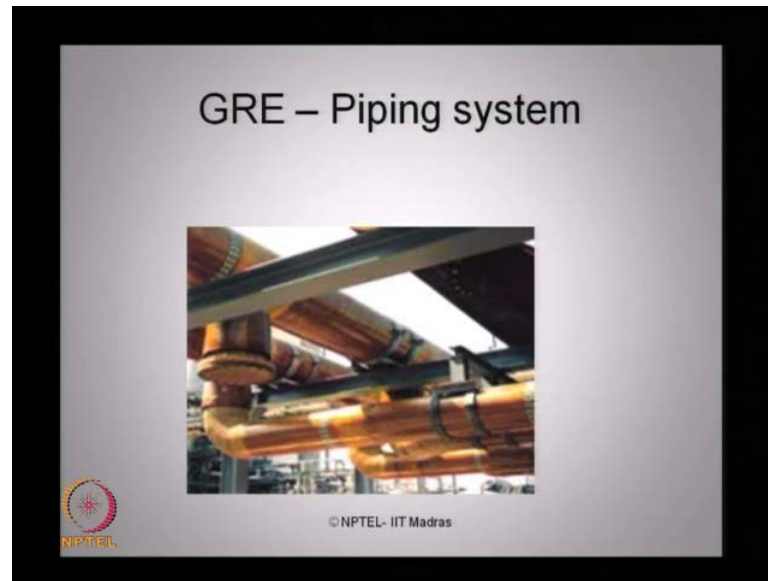
relating to material selection for composites are, smoke and toxicity in fire, mechanical properties including resistance to impact and adverse environments.

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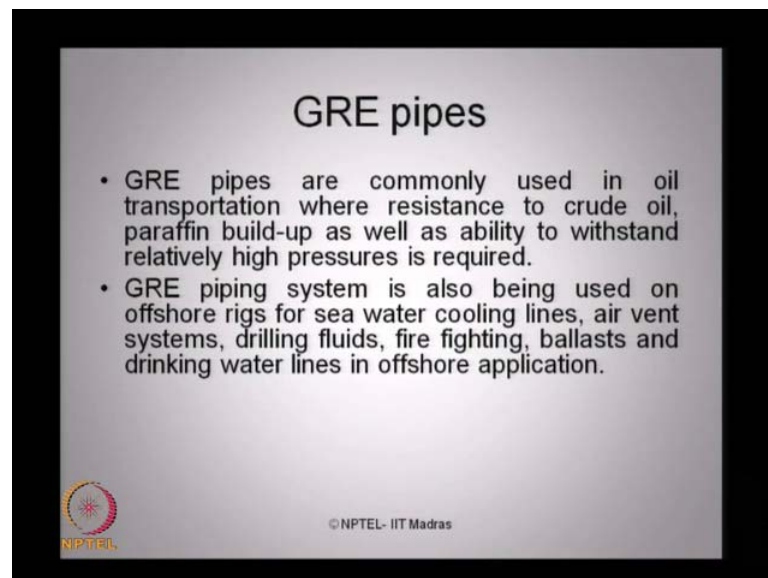
So, composites are recommended very fairly for piping system, as we saw in the previous guide. G R E is one of the important composite, which is glass rein force epoxy resin which it is a piping system which is suitable for offshore environment against highly corrosive fluid at various pressure, temperature, soil in weather conditions. G R E is popularly being used now, for oil exploration, desalination, chemical plants, fire mains, and dredging etcetera.

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Here is a photograph of a G R E piping system used in one of the top steel process plant and offshore industry.

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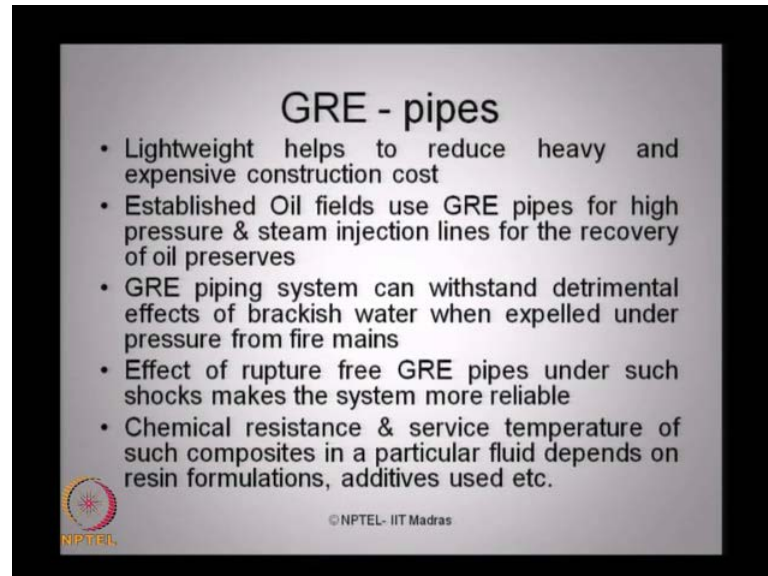


G R E pipes are very common, in all transportation as well, where resistance the crude oil, paraffin build up as well as ability with stand relatively high pressure are required as a important characteristic in case of transportation. G R E piping system is also being use on offshore rigs for sea water cooling lines, air vent systems, drilling fluids, fire fighting



systems, ballast systems, drinking water lines in many other applications in offshore segment.

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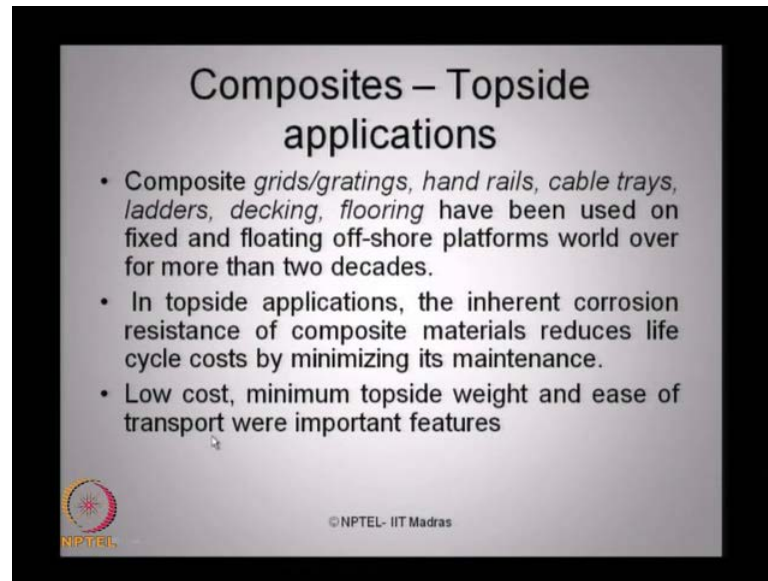


G R E pipes have light weight pipes and therefore, reduce the weight and the construction cost as well as, piping system is concern in offshore industry. They establish oil fields use G R E pipes for high pressure and steam injection lines for recovery systems. G R E piping system can be with stand detrimental effects of brackish water when expelled under pressure from fire mains.

Effect of rupture free G R E pipes under such, shocks make the system more reliable therefore; people get attracted of using G R E piping system for fire retardation or fire piping systems as well as recovery systems in oil preservations. Chemical resistance, service temperature of such composites and particular fluid basically, depends on the resin formulations, additives being use to manufacturing methods et cetera.


So, we are not discussing about the chemical manufacturing process and methodologies of manufacturing G R E pipelines are composites as a material but this lecture focuses on how composites can be saying it is a very effective alternative of construction material in offshore industry.

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**Composites – Topside applications**

- Composite *grids/gratings, hand rails, cable trays, ladders, decking, flooring* have been used on fixed and floating off-shore platforms world over for more than two decades.
- In topside applications, the inherent corrosion resistance of composite materials reduces life cycle costs by minimizing its maintenance.
- Low cost, minimum topside weight and ease of transport were important features

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Composites also have very wide variety of applications in the top side. Composites grids, gratings, handle rails, cable trays, ladders, decks and flooring in offshore industry has become recently increasing, which have been used for fixed and floating offshore platforms world over. In top side application, the inherent corrosion resistance of composite material reduces, ladies and gentlemen the life cycling cost by minimizing its maintenance actually.

The low cost minimum top side weight and ease of transport were important features can be seeing as list of advantages of using composites as top side material in marine applications.

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Here is a photograph which shows you the use of hand railing, grating in the pipeline where, we have used composite material as an alternative to steel.

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There are other non- ferrous materials which can be also used in offshore construction. For example, cupronickel alloy which is mixture of copper and nickel in the percentage of 69 and 30 is an alternative material for construction offshore industry. The other one which is very popular and being used is K Monel alloy, which is combination of nickel

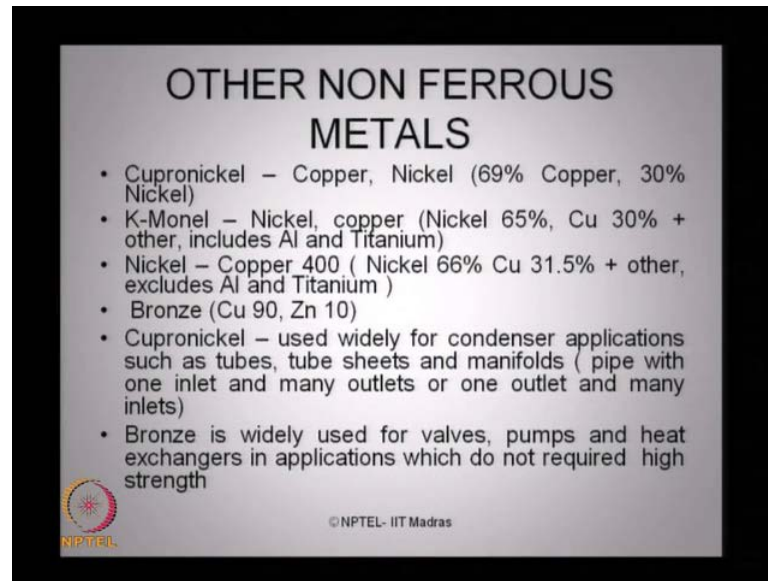
and copper at 65 30, and the other material like aluminium and titanium are also being included in fabricating a manufacturing this K Monel alloy.

The next competitive of down the line the race is nickel copper 400 which contributes 66 percent in nickel and 31.2 percent from copper and other material which excludes aluminium and titanium. Bronze is also finding increase applications in offshore constructions C u 90 and zinc 10 percentage, been used in this. Cupronickel is a very common and popularly use alloy, which is widely used in condenser applications such as, tubes, tube sheets and pipelines manifolds with one inlet and many outlets or one outlet and many inlets.

So, you have got different kinds of material which has been competitively being recommended offshore application. Ladies and gentlemen, we are slowly getting into the details of different kinds of materials which are recommended for offshore application remember carefully, the material mechanical properties, structural characteristics their selection, their classification, their applicability, their treatment, their fabrication is their transportation all factors do mad an engineer to find out whether pitch material should be properly used.


If you see I can also recommend material based on international recommendations given by the codes. Various codes recommend material for different applications; however, the variety of these applications makes an engineer to select the suit over material for the require service life of an offshore application. In the next lecture will talk about more a different other kinds of material as we see from the lecture here.

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**OTHER NON FERROUS METALS**

- Cupronickel – Copper, Nickel (69% Copper, 30% Nickel)
- K-Monel – Nickel, copper (Nickel 65%, Cu 30% + other, includes Al and Titanium)
- Nickel – Copper 400 ( Nickel 66% Cu 31.5% + other, excludes Al and Titanium )
- Bronze (Cu 90, Zn 10)
- Cupronickel – used widely for condenser applications such as tubes, tube sheets and manifolds ( pipe with one inlet and many outlets or one outlet and many inlets)
- Bronze is widely used for valves, pumps and heat exchangers in applications which do not required high strength

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There are alternative non- ferrous materials like cupronickel, K Monel, nickel, bronze which are widely used for different upper tenancies lie valves, pumps, heat exchangers where no other material can substitute the strength and the functional requirements.

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**In the next lecture we will discuss about NON METALIC MATERIALS**

- Fibre glass
- Glass (tempered)
- Wood
- Concrete
- Ferrocement

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In the next lecture, we will discuss about more non- metallic materials like, fibre glass tempered glass, wood, concrete, ferrocement etcetera.

Thank you.