Basics of Mechanical Engineering-1

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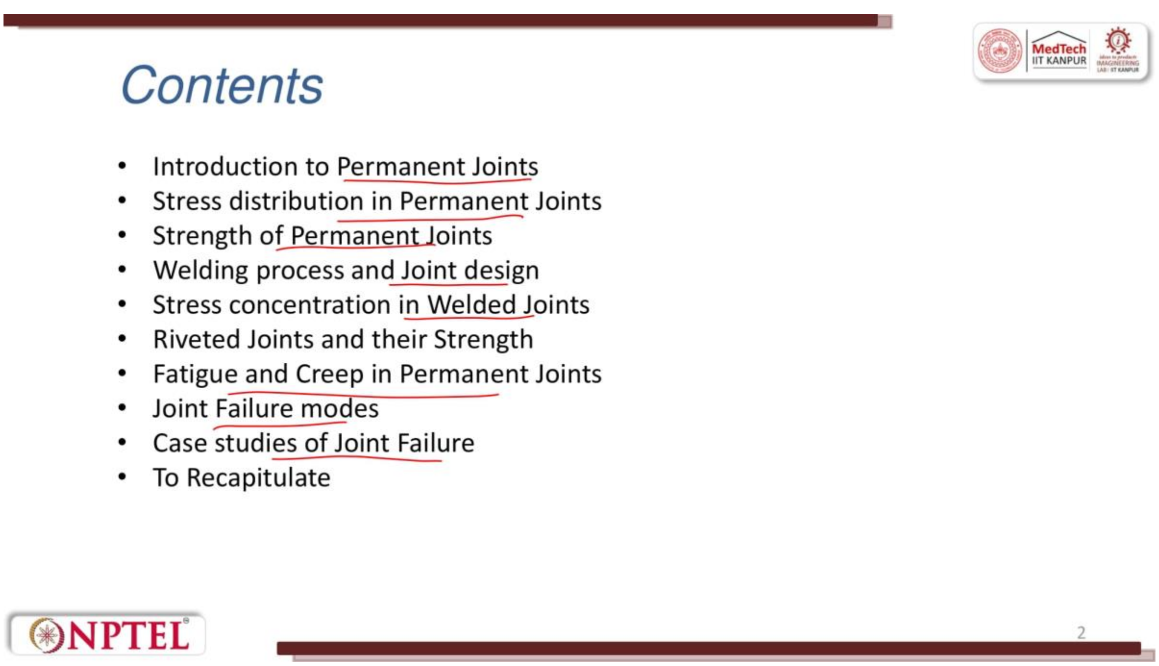
Week 12

Lecture 48

Permanent Joints

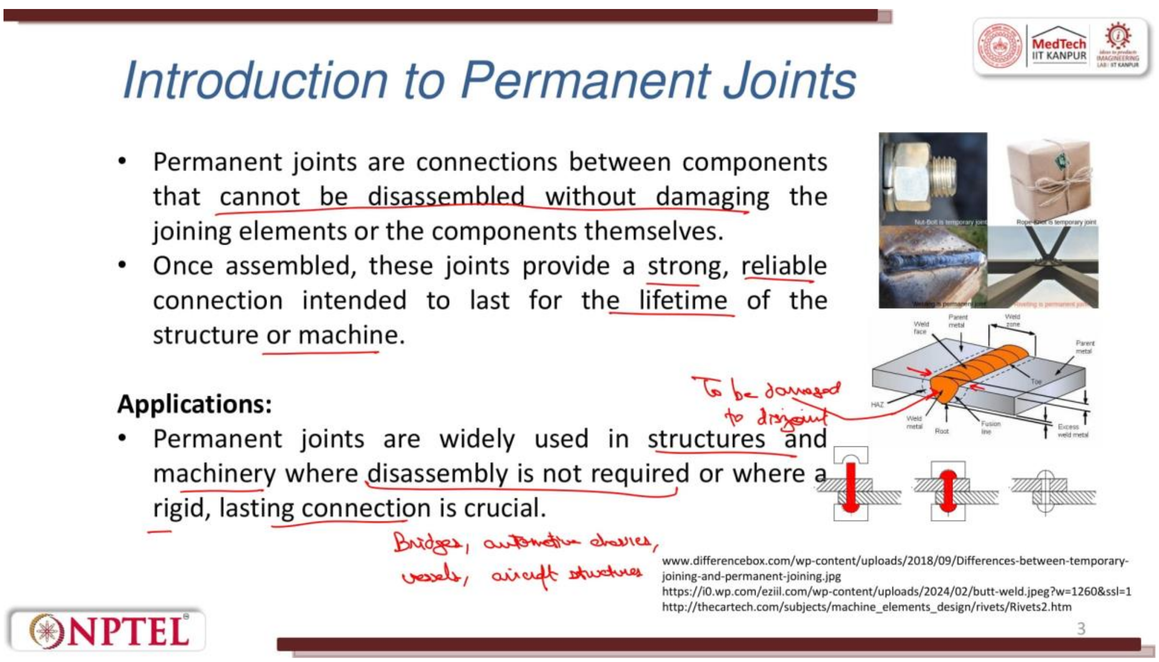
Welcome to the last week of the course, this is of mechanical engineering 1. In week 12, first lecture is on Permanent Joints. Permanent Joints, we have discussed about various hardware used in the machine elements such as bolts, nuts, screws, fasteners, those were majorly the temporary joints. Permanent joints were also discussed to small extent. For example, we discussed about rivets.

Rivets could be temporary, rivets could be permanent. In this lecture, we will talk about the permanent joints only. When we talk about rivets in this lecture, we will talk about the permanent rivets.



The flow of lecture will go in such way. We will talk about the Permanent Joints, introduction to it, then Stress Distribution in Permanent Joints, Strength of Permanent Joints, Welding process and Joint Design welding is one of the permanent joints generally welding is there when we talk about permanent joint the first thing that we talk about.

Stress Concentration in Welded Joints, Riveted Joints we will talk about, we will just give you more details on riveted joints and the kind of the Failures and Fatigue that is there in permanent joints. Joint Failure Modes. Some case studies we will see that why and where joint failure happened and what was the catastrophic failure because of it.

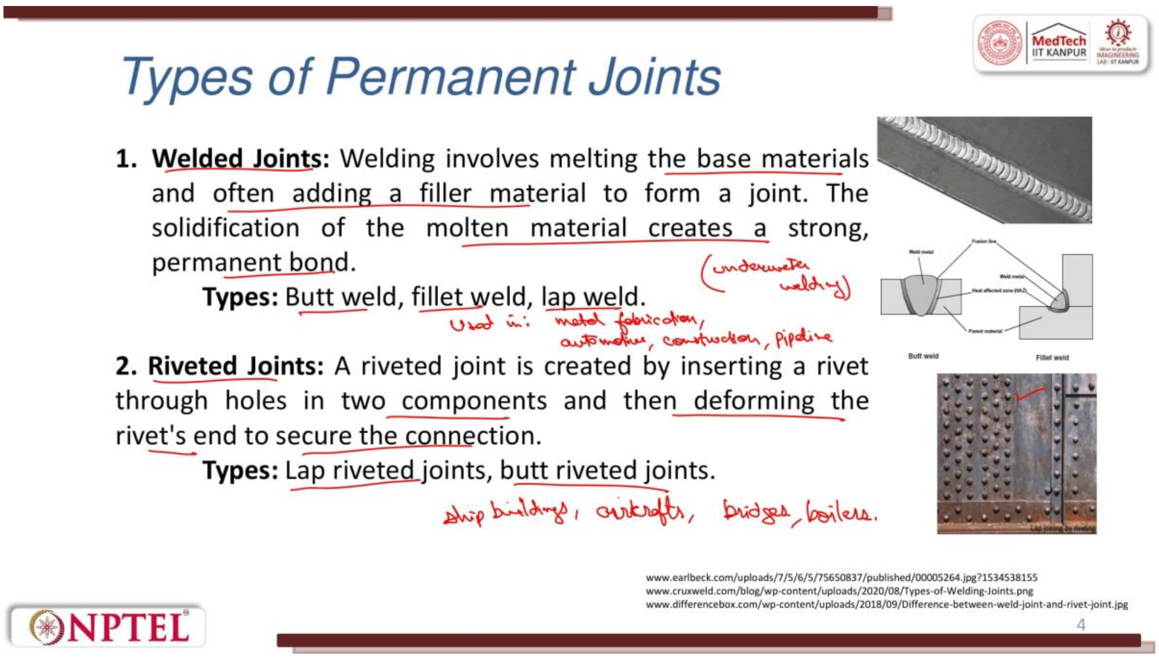


Introduction to Permanent Joints. Permanent joints are connections between components that cannot be disassembled without damaging.

It cannot be disassembled without damaging the joining element or the components themselves. So, when the permanent joint is made, if two parts are joined permanently, they have to be damaged from here to be damaged to disjoint. Once assembled, these joints provide strong, reliable connection intended to last for the lifetime of the structure of a machine. Full machine element cannot be built in one go. For example, if you wish to build complete fuselage of an aircraft, that full structure could not be built in one go.

Different sheets are there, those are joined using rivets. But those behave as a permanent joint that cannot be disassembled. Applications of the permanent joint are many. Permanent joints are widely used in structures and machinery where disassembly is not required or where a rigid lasting connection is crucial. Certain examples could be bridges, automotive chassis,

And any such big or bulky systems, for example, vessels, boiler vessels or so, then I talked about aircraft structures.



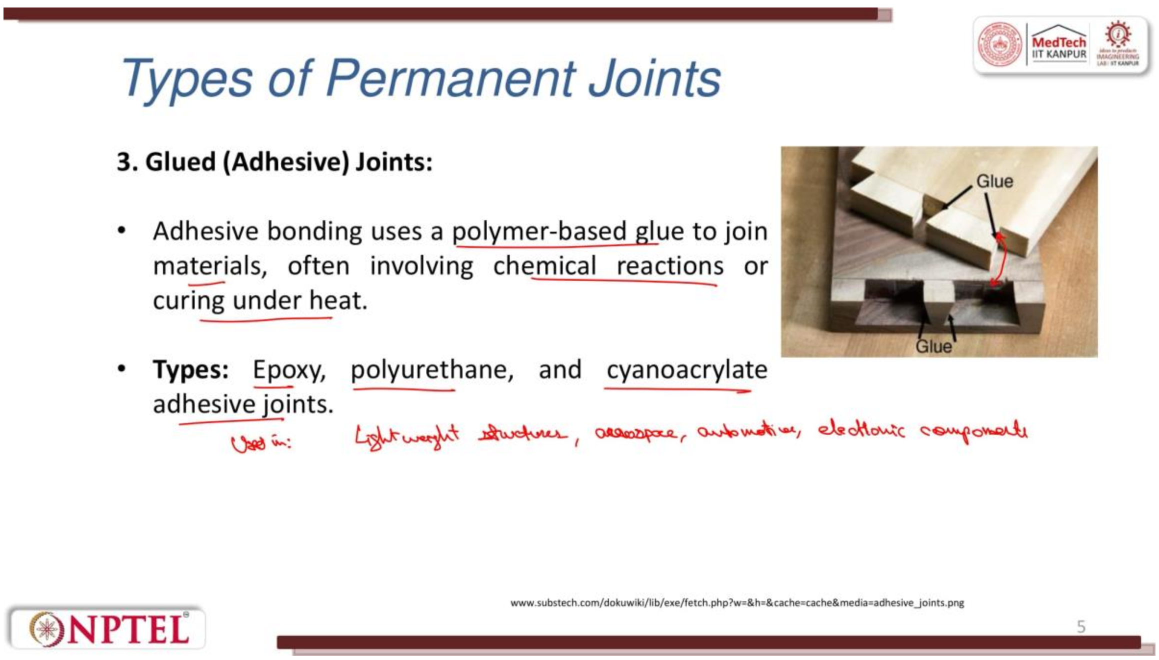
Talking about the permanent joints, when we talk about the types of them, Welded joints and Riveted joints, then we have glued joint as well. Welding involves melting the base materials and often adding filler material to form a joint. The strong solidification of molten metal creates a strong permanent bond. Butt weld, fillet weld, lap weld are the types of welding joints and commonly these are used in metal fabrication.

Metal fabrication, automotive, construction, pipeline systems, there is nowadays even underwater welding. So, multiple applications could be there. Then comes Riveted joints. Riveted joint is created by inserting a rivet through holes into components and then deforming the rivets end to secure the connection. So this is a riveted joint.

This is the permanent joint. It could be of butt type. It could be of lap type. We'll talk about the types of them. Types could be lap riveted joints, butt riveted joints.

So these have a big history of being used in shipbuildings, Air cross I have already mentioned. Bridges, Boilers. But now, before the advent of the welded joints, rivets only have a huge history or long history of being used to join or make big structures in construction, in boilers, in any of the structures like those. Now, as the welding technology is developed to even advanced level, we are able to even weld aluminium nowadays.

So, there are 3D printing systems using welding itself, depositing the material using welding. Technological developments say that they are in welding which has now reduced the use of riveted joints but still rivets has a huge applications in aircraft building or so.



Then comes Glued joints adhesive bonding uses polymer based glue to join materials often involving chemical reactions under heat and the squaring happens under heat this is glued joint that could used on wood here.

So, types of the glues those are leading to permanent joints are epoxy, polyurethane, cyanoacrylate, adhesive joints. Applications for Glued joints are generally the structures which are lightweight structures used in these then aerospace automotive and when we are talking about the lightweight structures we should also put here the electronic components.

Advantages and Disadvantages

Advantages:

- High strength and reliability.
- No additional hardware needed. No need of bolts, nuts, screws etc.
- Can withstand heavy loads, making them suitable for structural applications.

Often more aesthetically pleasing

Disadvantages:

- Non-reversible; components cannot be disassembled without damage.
- Requires specialized equipment and skilled labor. welding training
- Difficult to inspect for internal flaws. (welding joints)

Next is advantages and disadvantages of the permanent joints. Advantages are they have high strength and reliability. There is no additional hardware that is required. For example, there is no need of bolts, nuts, screws, etc.

They can withstand heavy loads, making them suitable for structural applications. They are often more aesthetically pleasing. Because there are no visible fasteners, so they are machined in such a way post joining that aesthetically they are more pleasing. Disadvantages are they are non-reversible. As I said, the part itself has to be damaged to disjoint.

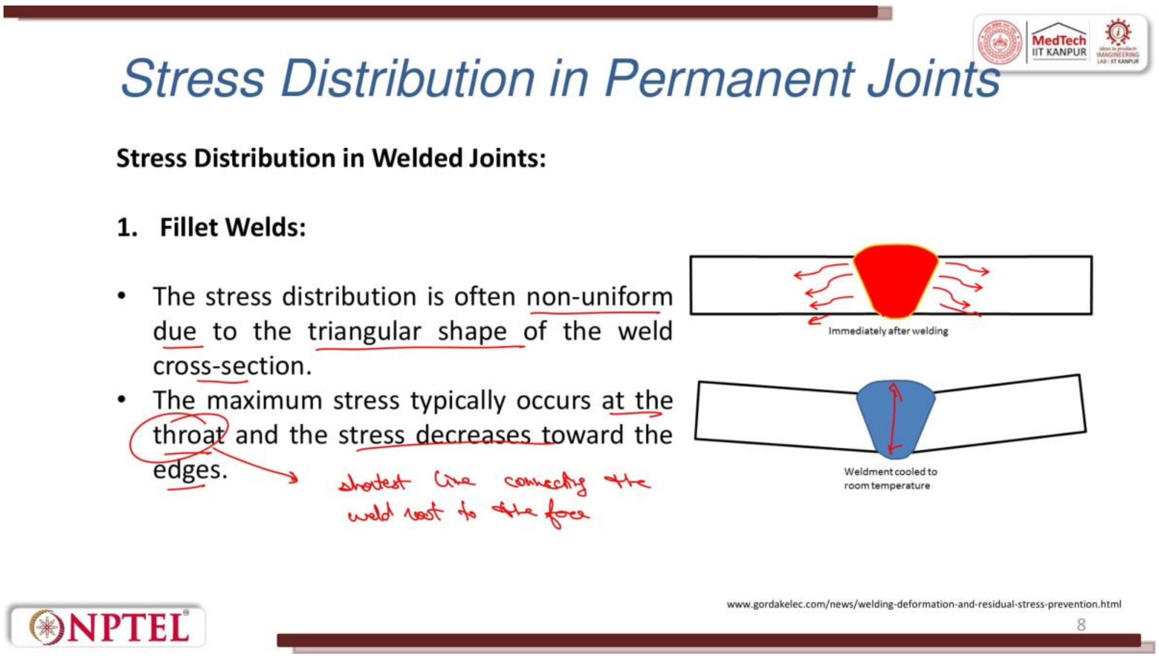
Components cannot be disassembled without damage. These require specialized equipment and skilled labor. For example, in welding, training is required. So, specialized skill is always difficult to inspect for internal flaws. Yes, for example, if welding joint itself is there, internal joints or internal flaws is most of the times not possible.

Comparison with Temporary Joints (e.g., Bolts, Nuts):

- **Advantages of Temporary Joints:**
  - Reusable and easily disassembled for maintenance or repairs.
  - Allow for easy replacement of components.
  - Simpler to inspect for wear and tear.
- **Disadvantages of Temporary Joints:**
  - Less rigid and may loosen over time.
  - Can be bulkier due to the need for bolts, nuts, and washers.
  - Susceptible to fatigue and failure under dynamic loads if not maintained properly.

Now, when we compare the permanent joints with temporary joints, for example, bolts and nuts. The advantages of temporary joints are these are reusable, they can be easily disassembled for maintenance or repairs, they allow for easy replacement of components, they are simpler to inspect for wear and tear because this can be disassembled. On the other hand, the disadvantages of temporary joints are they are less rigid and may loosen over time.

They can be bulkier due to need of the external hardware like bolts, nuts, washer, they all add to the weight of the final assembly. They are susceptible to fatigue and failure under dynamic loads if not maintained properly.



Let us now talk about Stress Distribution in Permanent Joints. Stress distribution in welding joints, when we talk about, we will talk about the Fillet welds and Butt welds. The stress distribution is often non-uniform due to triangular shape of the weld cross-section. So, this is a Fillet weld that is there.

So, immediately after welding, you can see the stress lines are like this. Stress distribution is going in this direction. Maximum stress typically occurs at the throat and stress decreases towards the edges. What is throat? This is the shortest line connecting the weld's root to the face.

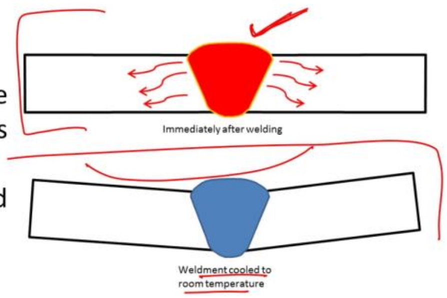
So, weld route to face when we connect, this is throat. So, I will put it as throat is shortest line connecting the weld route to the face.

Stress Distribution in Permanent Joints

Stress Distribution in Welded Joints:

2. Butt Welds:

- Stress is more evenly distributed across the weld, especially if the joint preparation is precise.
- However, misalignments or poor weld quality can cause stress concentrations.



www.gordakelec.com/news/welding-deformation-and-residual-stress-prevention.html

In the butt joint, stress is more evenly distributed across the weld, especially if the joint preparation is precise. So, this is a butt joint. However, misalignments or poor weld quality can cause stress concentrations here.

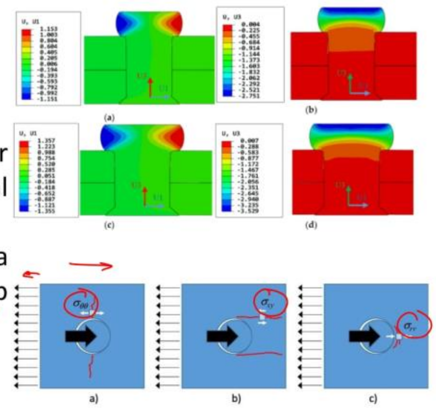
So, this is the joint when it was hot, which means in the joining time itself, this is how the stress follows and later it contracts. So, there is misalignment or angular deformation that has happened when the joint has come to the cooled or room temperature.

Stress Distribution in Permanent Joints

Stress Distribution in Riveted Joints:

1. **Shear Stress:**

- Riveted joints primarily experience shear stress, distributed over the cross-sectional area of the rivet.
- In a single lap joint, the rivet experiences a double shear force, while in a double lap joint, the rivet bears the load more evenly.



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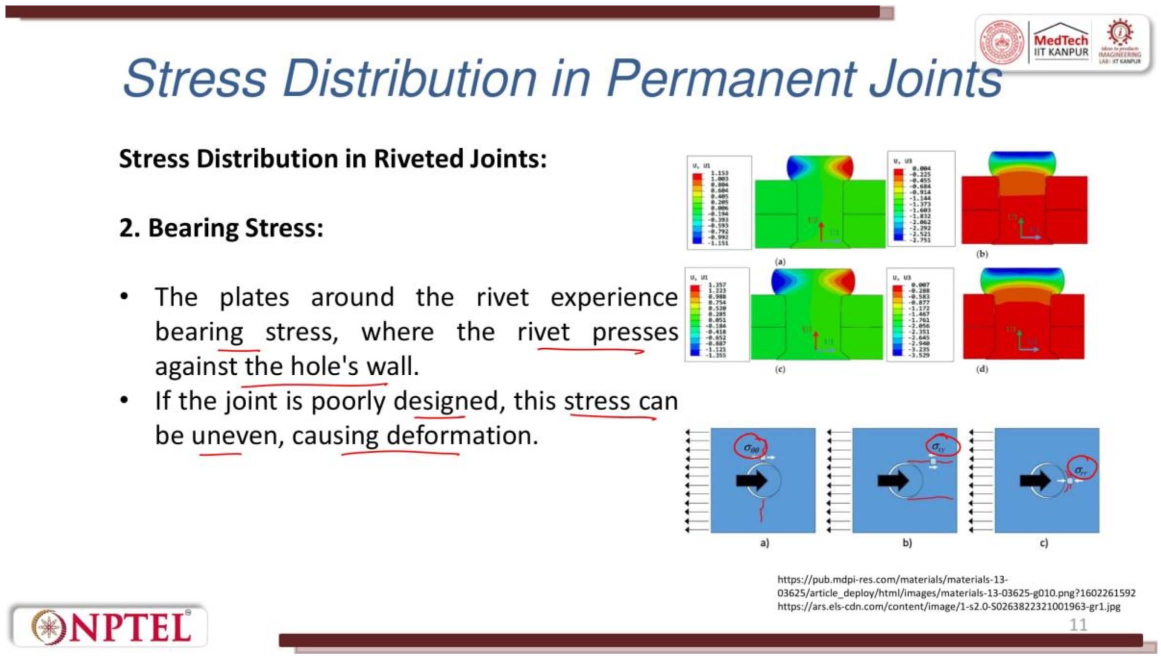
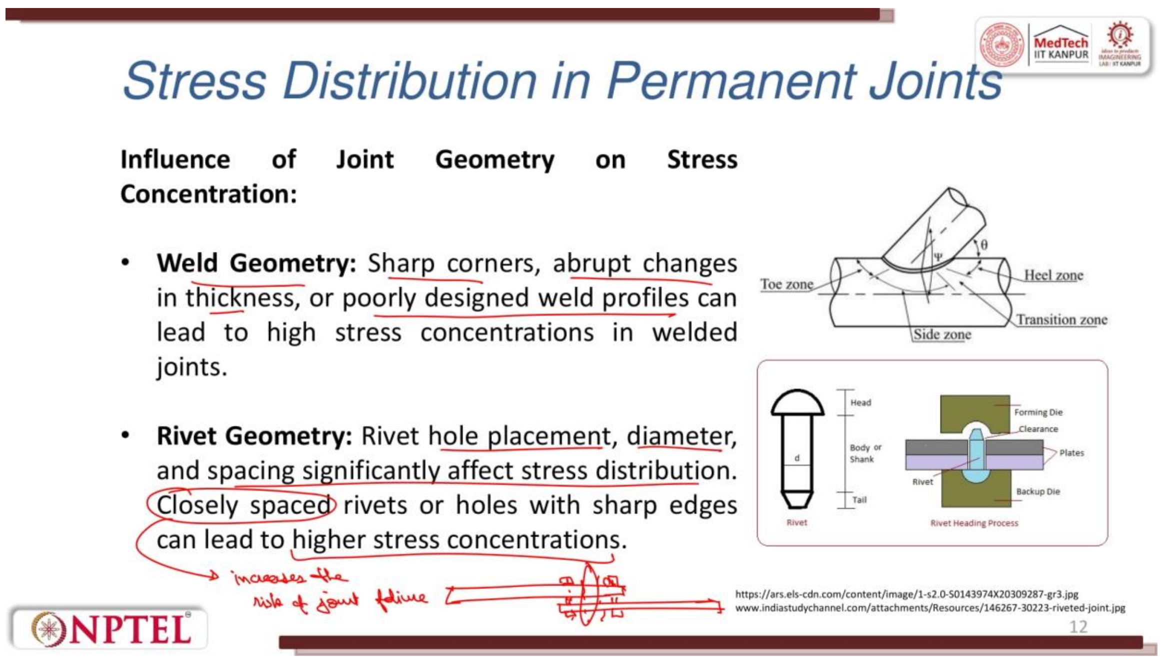
Next is the Stress distribution in Riveted joints. Here it is showing shear stress is there riveted joints primarily experience shear stress distributed over cross sectional area of the rivet.

In a single lap joint, the rivet experiences a double shear force while in a double lap joint. The rivet bears load more evenly. So, it depends upon what kind of the load is there. So, stress distribution is also like this. You can see in this direction stress is there and here the stresses are going. So, this is σθθ σxy σrr. The stress is distributed in this direction.



Then we have Bearing stress. So this is bearing stress you can see σθθ σxy σrr. So here the plates around the rivet experience bearing stress where rivet presses against the hole's wall. If the joint is poorly designed, this stress can be uneven causing deformation.



So, Influence of Joint Geometry on Stress Concentration. Weld geometry plays a big role. Sharp corners, abrupt changes in thickness or poorly designed weld profiles can lead to high stress concentrations in a welded joint. So, designing of the weld depending upon the strength that is required is an important factor here. In Rivet geometry, rivet hole placement diameter of the hole and spacing significantly affect the stress distribution spacing between the rivets.

Closely spaced rivets or holes with sharp edges can lead to high stress concentrations. Also, if joint is to be made between two parts, this is part 1 and part 2, it depends how close are you placing rivets. If it is very close, the stress concentration would be high. If it is far, if you put one rivet here, in the rivet for a stress concentration would be lesser in the middle area.

So, close placing of rivet not always mean the joint is very strong because very close placing of rivet also increases the risk of failure due to stress concentration. So, I will write it here the closely spaced rivets increases the risk of joint failure.

Strength of Permanent Joints

Factors Affecting Joint Strength

1. Material Properties
2. Joint Design
3. Quality of the Joint

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Next comes strength of woman joints. Strength is affected by the factors such as Material Properties, Joint Design and Quality of the Joint.

Strength of Permanent Joints

Factors Affecting Joint Strength

1. **Material Properties**:

- **Tensile Strength**: Higher tensile strength enhances joint strength.
- **Ductility**: Greater ductility improves toughness.
- **Thermal Properties**: Good thermal conductivity prevents defects.
- **Corrosion Resistance**: Essential for long-term integrity.

Regarding the Material Properties, Tensile Strength: higher tensile strength enhances the joint strength.

Ductility: greater the ductility, more is the toughness. So ductility improves toughness. Thermal properties: good thermal conductivity prevents defects. Corrosion Resistance: essential for long term integrity if the joints are to be made and we cannot reach the internal flaws of the joint. So the material selection has to be such a way so that the corrosion resistance property is there.

Strength of Permanent Joints

Factors Affecting Joint Strength

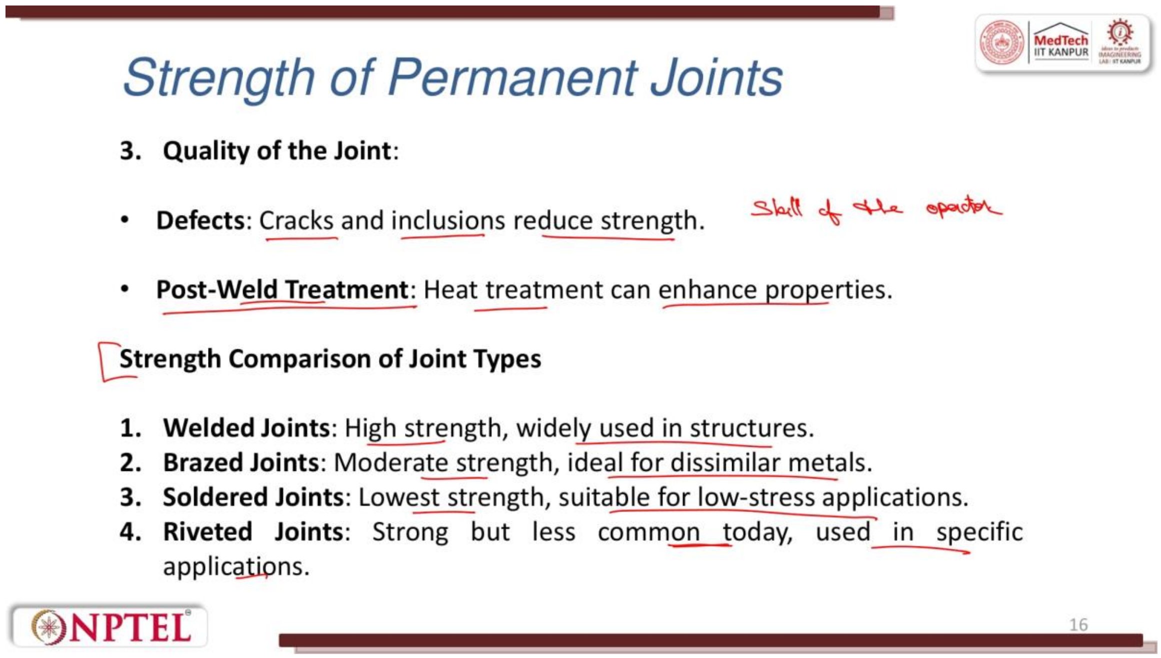
2. **Joint Design**:

- **Geometry**: Influences stress distribution.
- **Weld Size and Type**: Larger and appropriate weld types yield higher strength.
- **Preparation and Fit-Up**: Proper alignment and surface preparation are crucial.
- **Heat Input**: Affects metallurgical properties of the joint.

NPTEL

Next is Joint Design. Geometry of the joint largely influences the stress distribution. So that is very important factor. Weld Size and Type: larger and appropriate welds yield higher strength. Preparation and fit up.

Proper alignment and surface preparation. There are two factors. These are crucial. Heat input. This affects the metallurgical properties of the joint.



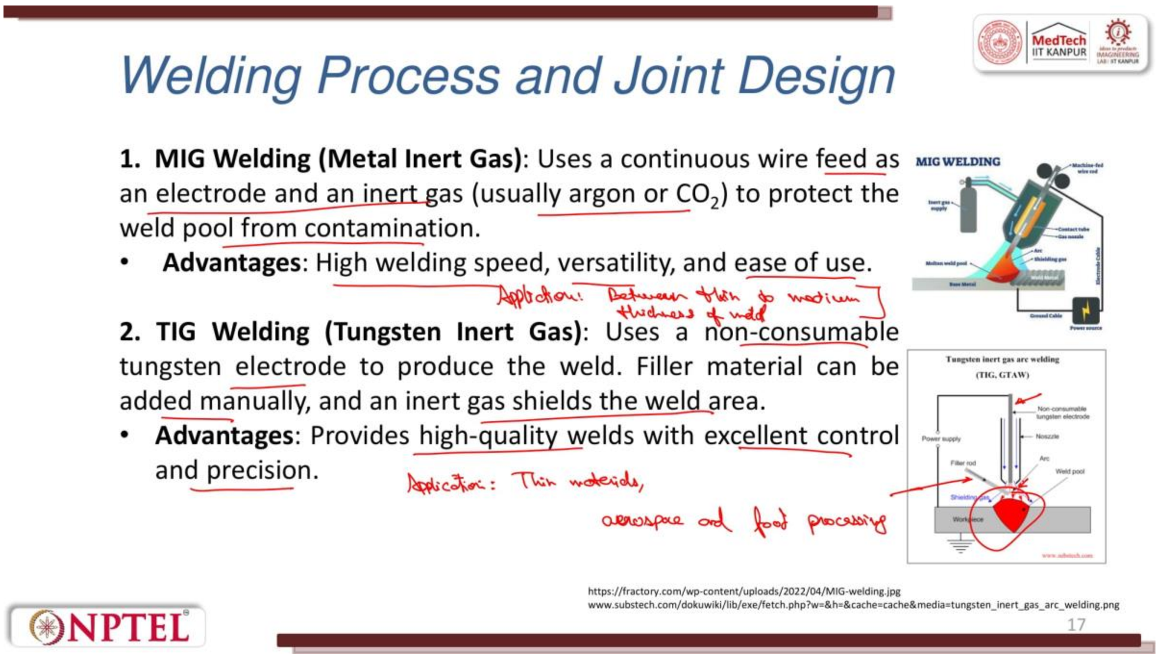
Then is the Quality of joint. Quality of joint that is the cracks and inclusions reduces the strength. It also depends upon the skill of the operator. That is a continuous joint. Joint without having any non-uniformity that is better.

Post weld treatment, heat treatment can enhance the properties. After the welding, heat treatment is given so that the properties are enhanced and the joint lasts longer. Strength comparison of joint types. Welded joints, high strength, widely used in structures. Brazed joints, moderate strength, ideal for dissimilar metals.

Soldered joints, lower strength, suitable for low stress applications, riveted joints, strong but less common today using specific applications only. Welding is when two metals have to be joined together, they could be melted and joined together, there could be filler in between that could be melted and the base material also melted and joined together. The filler material here is the same material that is the base material.

In case of base joints, the filler material is not same as the base material and this is the material that has a lower melting point that is the base material is sometimes not melted, only filler material is melted and these are joined this is brazing. Soldering is when brazing is done at a lower temperature for example, soldering is majorly used in electronic components at low temperature the filler material is different than the base material with a lower melting point and that helps to join the two base material or the two mating surfaces which are to be joined.

So that is the difference and riveted joints that is written here is less common today and these are used in specific applications only.

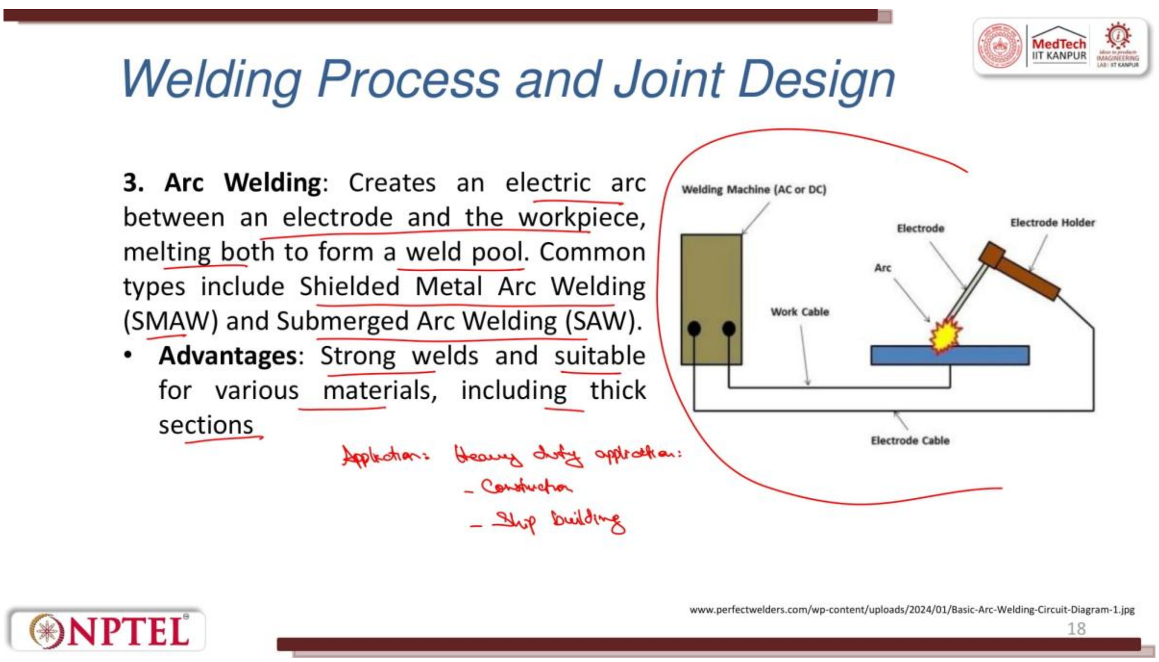


Next is Welding Process and Joint Design. Welding process could be MIG, could be TIG or it could be arc welding. MIG is 'Metal Inert Gas' welding that uses a continuous wire fed as an electrode and inert gas usually an argon or carbon dioxide gas to protect the weld pool from the contamination. We will discuss about the welding technology in the forthcoming course. The advantages of metal net gas welding is that it is a continuous process and it has a high welding speed, it is versatile, it is easy to use. Major application of the MIG welding is between thin to medium thickness of metal.

Application is between to medium thickness of metal and these are used in automotive and manufacturing industries Then comes TIG (Tungsten Inert Gas) that is a welding that takes place at a high temperature which uses a non-consumable tungsten electrode to produce the weld. Filler material can be added manually and an inert gas shields the welding area similar to what is there in MIG. In TIG, filler material is added separately. This is what is a TIG setup where separately filler material is there using a power supply.

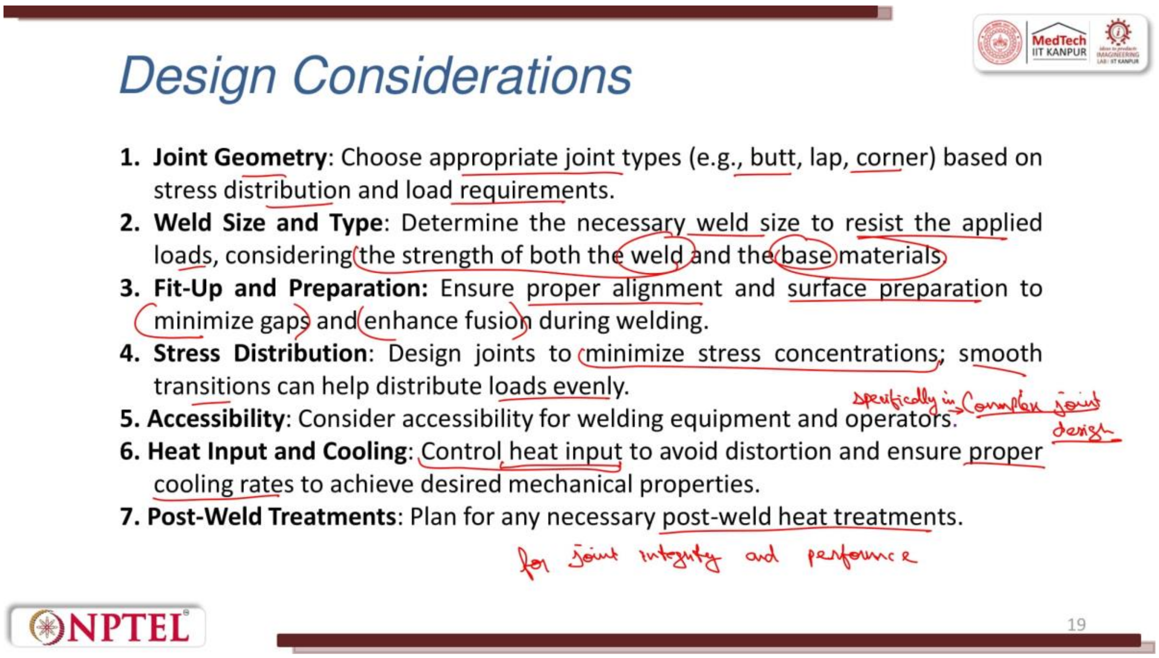
Electrical energy is there that provides this heat arc here and this is a weld pool where the welding is taking place and this is a non-consumable tungsten electrode that does not melt. Tungsten is a material that melts at very high temperature. So advantages of the TIG welding is it provides high quality welds with excellent control and precision because manually you are adding filler and you can have a better control.

It is ideal for again with thin materials and critical applications are aerospace and food processing. Could be multiple applications, wherever permanent joints are required, TIG welding could be used in many places, many other areas that we have even mentioned before.



Then comes Arc welding. Arc welding creates an electric arc between an electrode and the workpiece melting both to form a weld pool. Common types include shielded metal arc welding that is SMAW and submerged metal arc welding The advantages are it gives strong weld and suitable for various materials including thick sections. So applications are the heavy duty applications in construction and ship building.

Heavy duty applications such as construction and shape building. This is a setup for a metal arc welding.

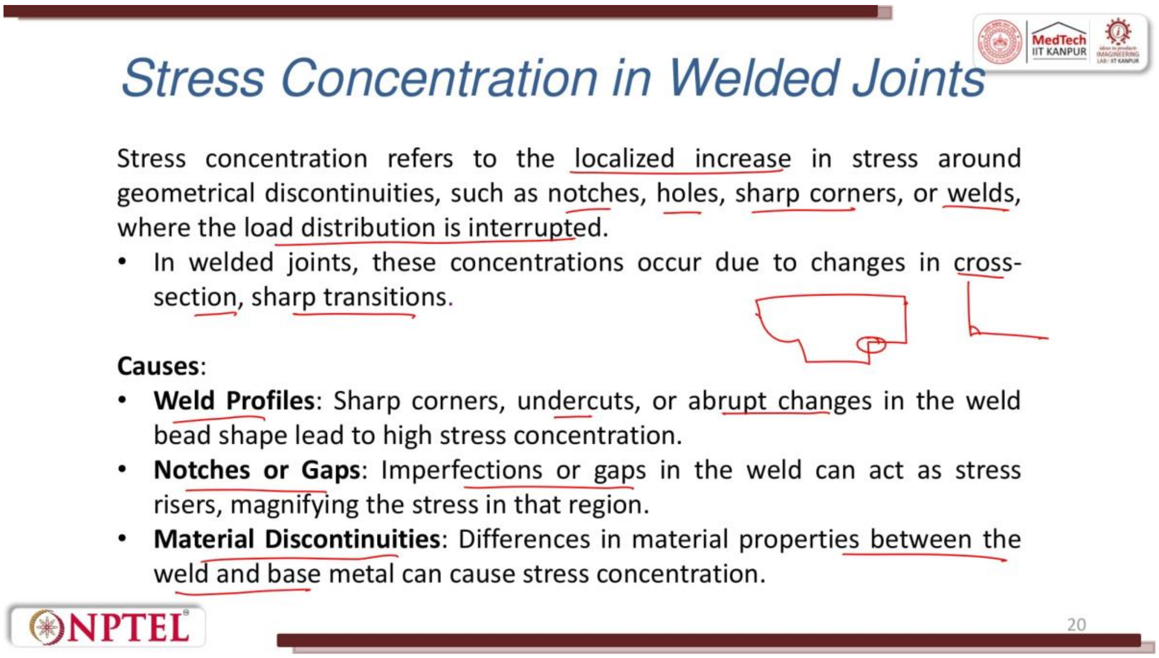


Design Considerations could be joint geometry, weld size and type, fit up and preparation that we have mentioned before. In Joint Geometry, we choose appropriate joint types that is whether to pick butt joint, lap joint or corner joint based on the stress distribution and load requirements. Weld Size and Type is picked.

Determining the necessary weld size to resist the applied loads is important. This considers the strength of both the weld and the base material. Fit-Up and Preparation. Now, we are talking about geometry and weld type. This also leads to fit up and preparation.

We ensure proper alignment and surface preparation. This is to minimize gaps and enhance fusion during welding. Stress Distribution, design joints to minimize stress concentration so as we get smooth transitions that can help distribute loads evenly. Consider accessibility for welding equipment and operators specifically when complex joints are there or complex design of the joints are there complex joint designs specifically in this. Heat input and cooling, control heat input to avoid distortion and ensure proper cooling rates to achieve desired mechanical properties.

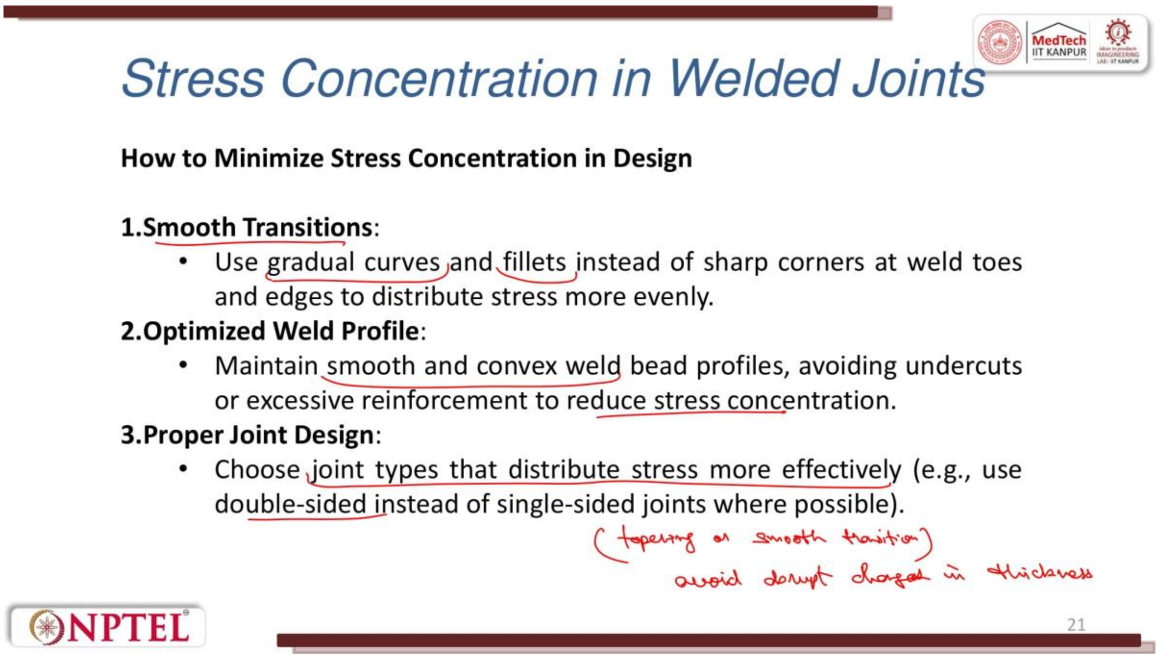
Proper cooling rates, whether cooling through air, cooling through water, what kind of the heat treatment or post weld treatment if we need to do to avoid that heat input and cooling can be controlled as well. Post-Weld Treatment: plan for any necessary post weld treatments that is post weld heat treatments. So, this is there to have joint integrity and performance as per the requirement.



Next is Stress Concentration in Welded Joints. Stress concentration refers to the localized increase in stress around geometrical discontinuities such as notches, holes, sharp corners or welds where the load distribution is interrupted.

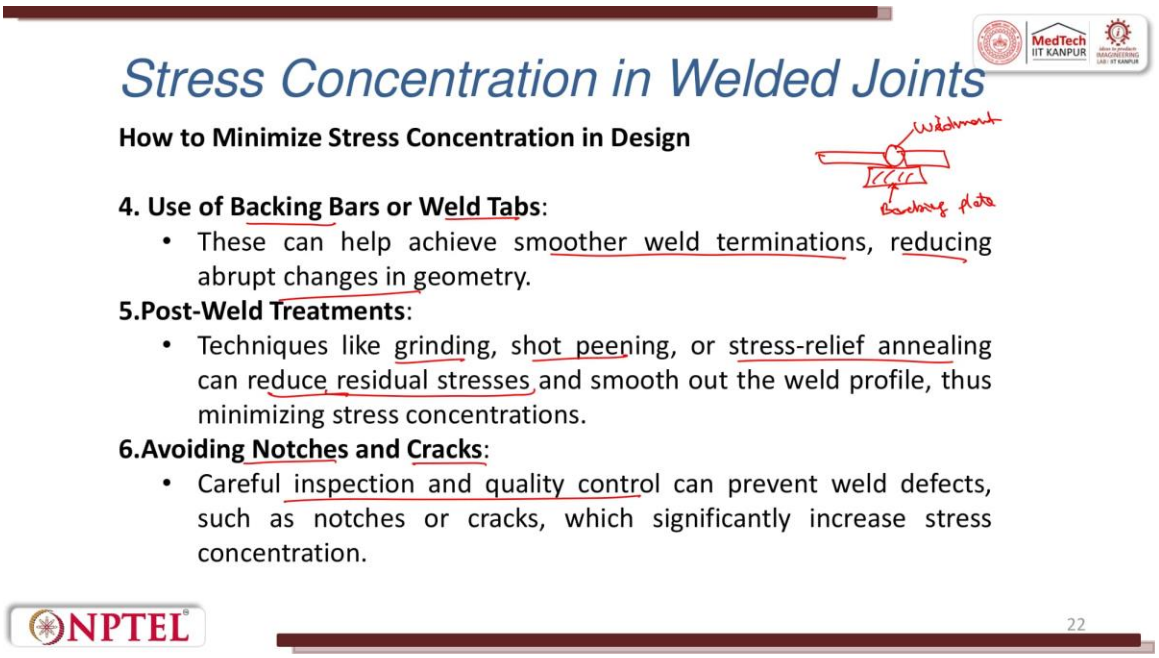
There could be material where corners are there. There could be systems with different corners, different circles, this kind of system could be there. So, when this is to be joined at some place example it is to be joined at a corner here somewhere. So, there this stress distribution becomes irrational. So, in welded joints these concentration occur due to changes in cross section sharp transitions or so.

The causes are Weld Profiles, Notches or Gaps, Material Discontinuities, sharp corners, undercuts or abrupt changes in the weld bead shape lead to high stress concentration. Notches or gaps, imperfection or gaps in the weld can act as stress sizes magnifying the stress in that region. Material discontinuities that is differences in the material properties between the weld and the base metal can cause stress concentration changes. These are all due to imperfections in the weld.



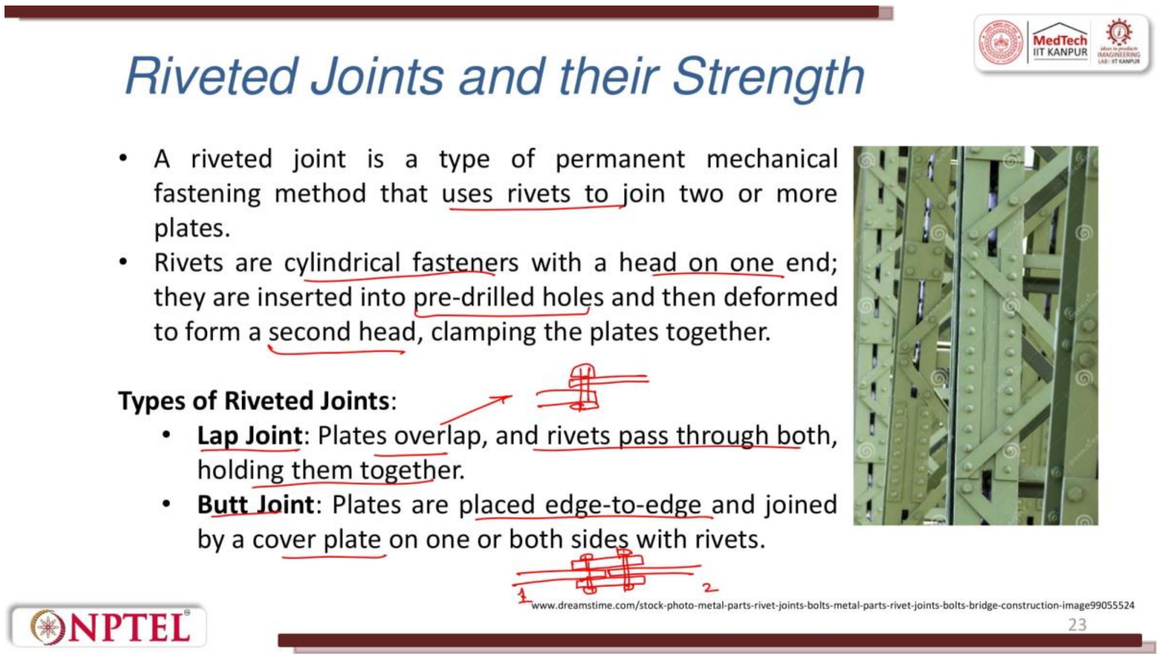
How to minimize stress concentration in design? One is Smooth Transition. We use gradual curves and fillets instead of sharp corners at weld toes and edges to distribute stress more evenly. Optimize the Weld Profile to maintain smooth and convex weld bead profiles, avoiding undercuts or excessive reinforcement to reduce the stress concentration.

Proper joint design to avoid the abrupt changes in thickness, we choose joint types that distribute stress more effectively. For example, we use double-sided instead of single-sided joints wherever possible and as I said to avoid abrupt changes in thickness, we can provide taper. Tapering could be done or smooth transition could be there in the surface. That is, we avoid abrupt changes. Changes in what? Changes in thickness.



Also, use of Backing Bars or Weld Tabs are there. These can help achieve smoother weld terminations reducing abrupt changes in geometry. Post-Weld Treatments techniques like grinding, shot peening, stress relief annealing can reduce residual stresses and smooth out the weld profile thus minimizing the stress concentrations. We can also avoid notches and cracks in that design itself, while careful inspection and quality control can prevent weld defects, such as notches or cracks could be avoided.

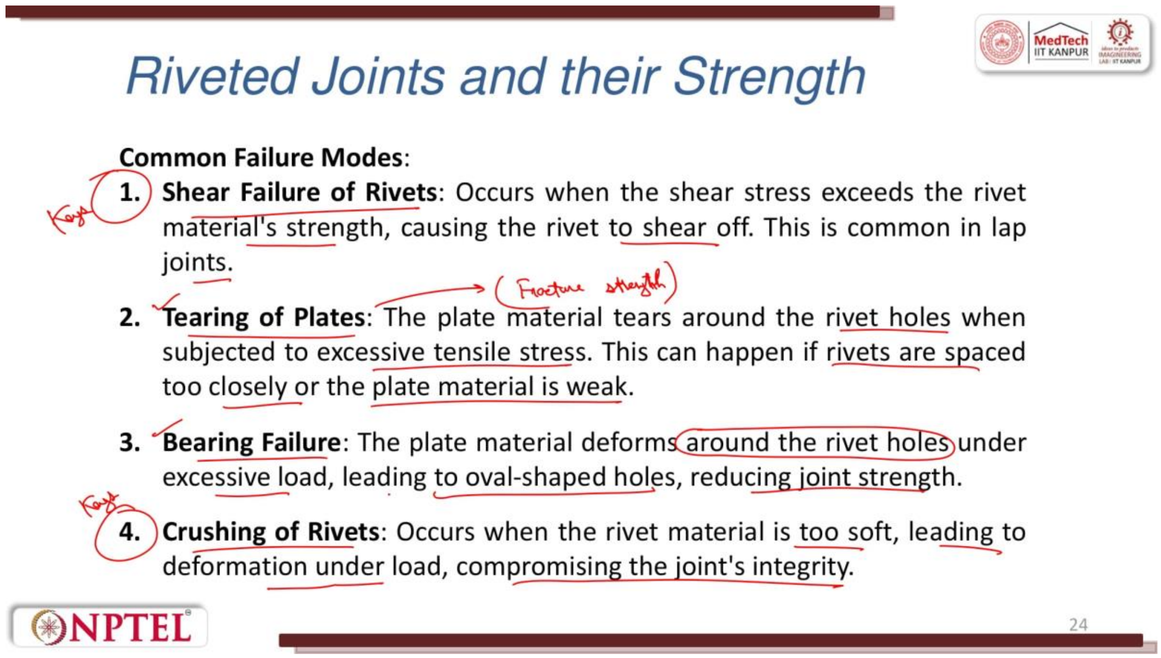
These significantly increase the stress concentration. Use your backing bar when I say, for example, this is to be joined, these two metals are to be joined and here weld is weldment I will put is here. So, a backing plate could be put here down so that the molten weld metal is supported and complete joint penetration is there. So, this is a backing plate.



Next is Riveted Joints and their Strength. Riveted joint is a type of a permanent mechanical fastening method that uses rivets to join two or more plates. Rivets are cylindrical fasteners that we have discussed. It has a head on one hand. They are inserted into the pre-drilled holes, then deformed to form a second head. Clamping the plates together, types of Riveted Joints that we did not discuss.

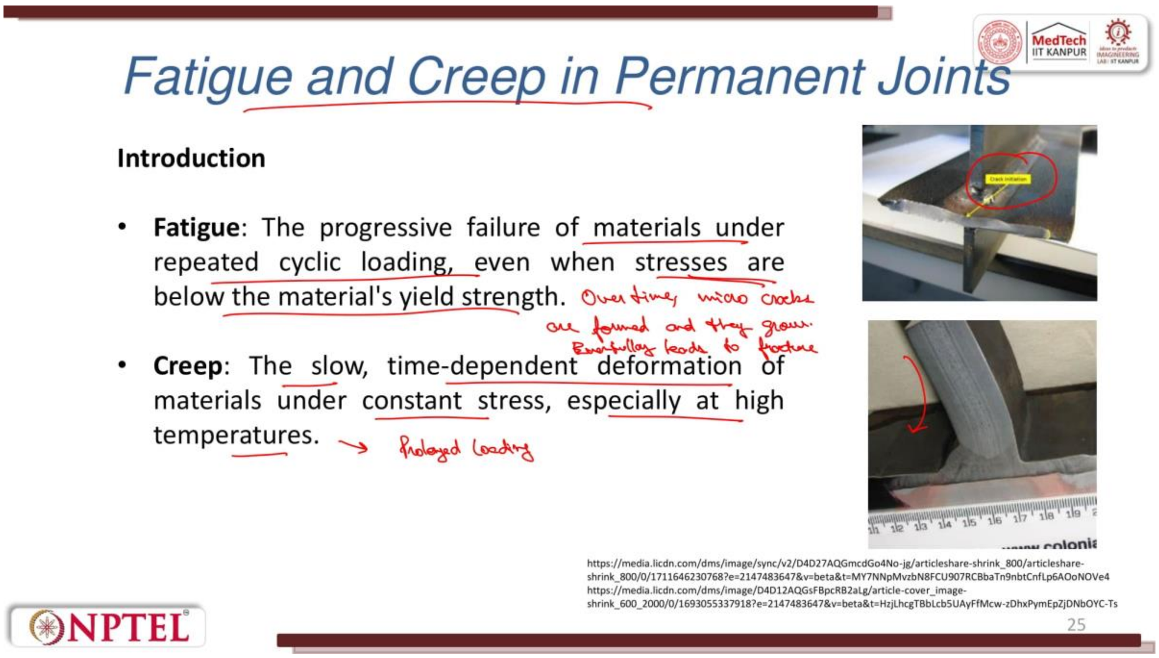
These could be Lap joint or Butt joint. Lap joint is when only they are lapped over each other. For example, this is one portion, this is second portion, this is lap joint in rivet. Here we put rivet. This is left joint, so left joint is plates overlap and rivets pass through both holding them together, this is left joint in what joint plates are placed as to edge and joined by a cover plate on one or both sides.

So these plates are placed end to end like this this is plate 1, plate 2, we add cover plates either on one side or on both sides and then rivet inserted over it. We add rivets here. This is butt joint.



Common failure modes in rivets. There could be Shear Failure of Rivets, Tearing of Plates, Bearing Failure, Crushing of Rivets. Shearing failure of rivets occurs when the shear stress exceeds the rivet material strength causing the rivet to shear off. This is common in lap joints that we have also discussed the shearing failure in the previous lectures. Tearing of plates, the plate material tears around the rivet holes when subject to excessive tensile stress. This can happen if rivets are spaced too closely or plate material is weak.

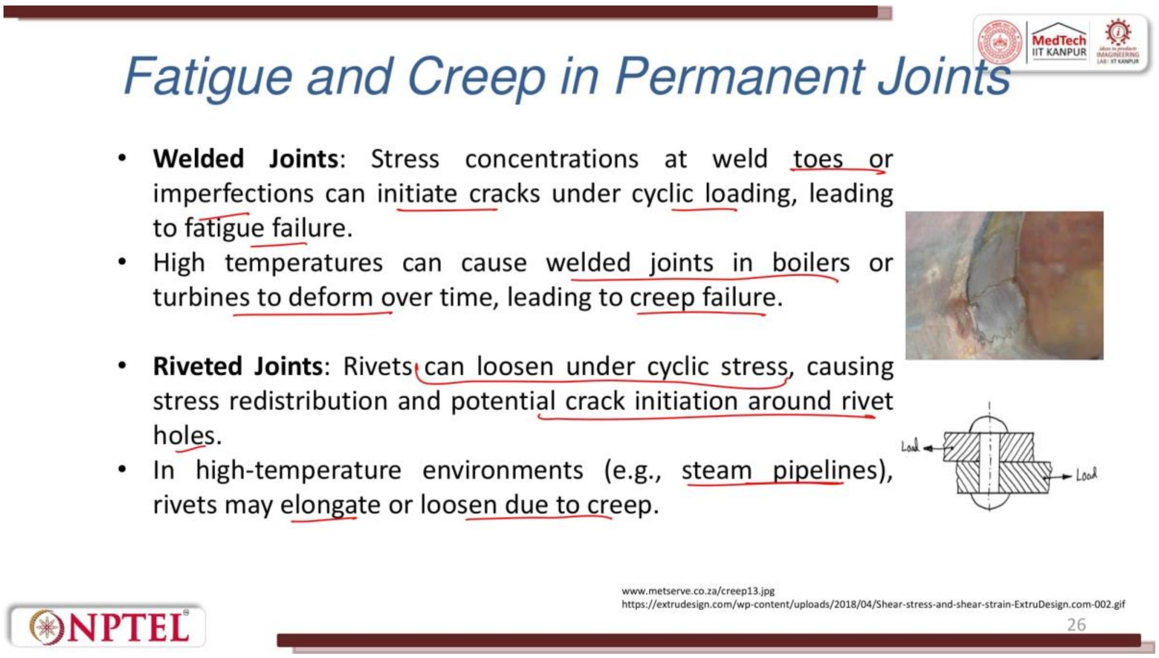
This is kind of a fracture strength; Bearing Failure is the plate material reforms around the rivet holes around the rivet holes that we have shown in the figure in the previous slides. So, around the hole under the excessive load leading to oval shaped holes reducing the joint strength crushing of rivets. Crushing occurs when rivet material is too soft leading to deformation under load compromising the joints integrity. So crushing and shearing was also in keys as you remember. But in rivets bearing is also there and fracture could also happen or tearing of plates could also happen.



Then comes Fatigue and Creep in Permanent Joints. When we talk about fatigue or creep, Fatigue, the progressive failure of material under repeated cyclic loading when stresses are below the material's yield strength. Though the stress is not exceeding the yield strength, but this is a load that is happening in a cyclic way. So, fatigue could happen. Creep, the slow time dependent deformation of material and a constant stress especially at high temperature that is creep.

You can see the fatigue failure that is the crack is getting initiated here and there could be creep because of creep there is a vent that is coming here. So over time micro cracks form and grow and fatigue is there. I would say over time. Micro cracks are formed and they grow. This eventually leads to fracture.

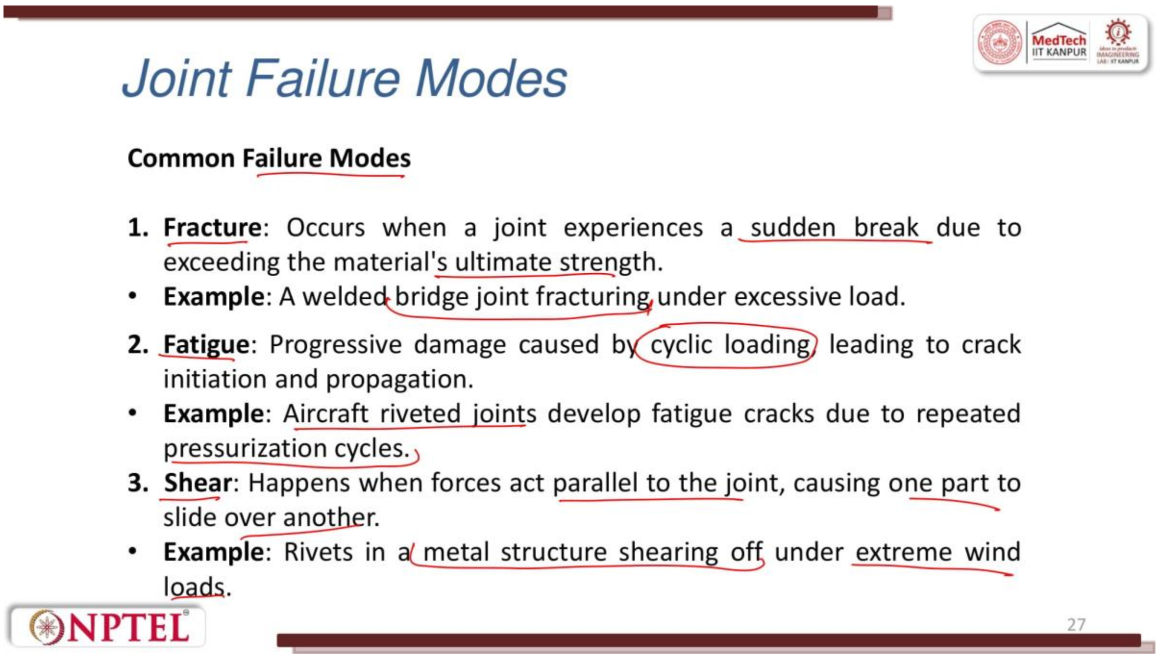
This is fatigue. In creep, it occurs due to subjected of prolonged loading. That is major reason for creep especially at high temperature it is given.



So fatigue and creep when we talk about the welded joints or riveted joints. In Welded joints stress concentration at the weld toes or imperfections can initiate cracks under cyclic loading leading to fatigue failure.

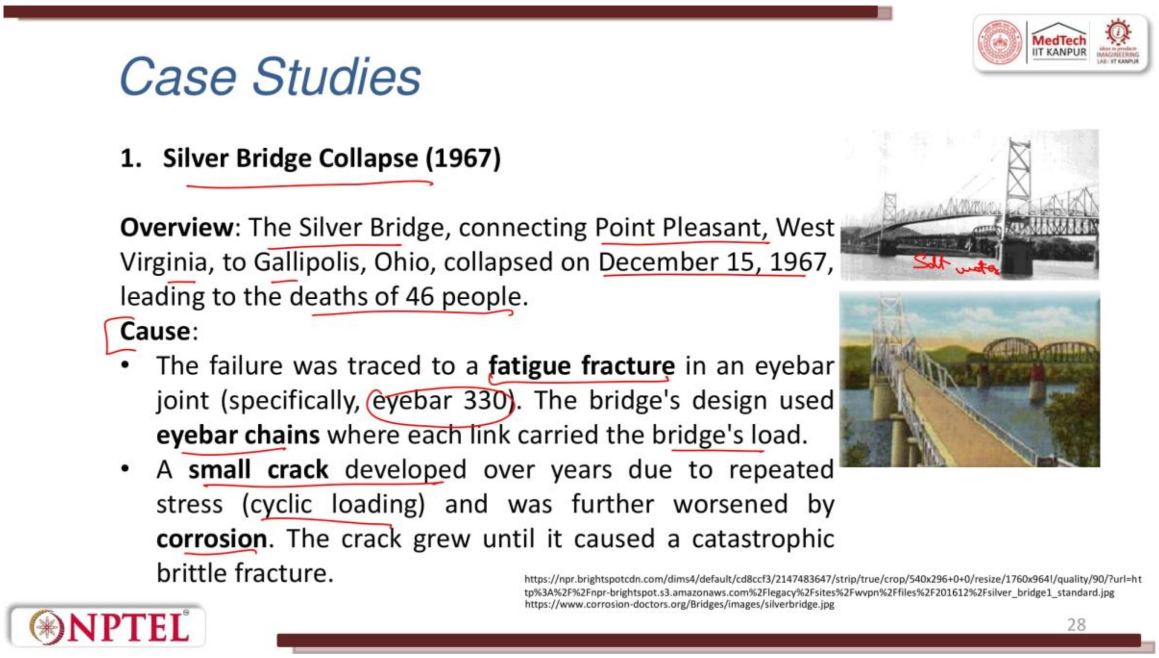
High temperatures can cause welded joints in boilers or turbines to deform over time leading to creep failure. In Riveted joints as well rivets can loosen under cyclic stress that is fatigue failure could be there. This causes stress distribution and potential crack initiation around the rivet holes. In high temperature environments such as in steam pipelines rivets may elongate or loosen due to creep. Examples are when the train passes through bridge time and again each day multiple trains are passing through a bridge and the bridges experience the vibration.

That vibration is there because of the vibration fatigue failure could happen because cyclic loading is there. We will talk about vibrations in the coming lecture as well. So, that is one of the examples where riveted joints could fail and aircraft also could be coated, aircrafts also are under the turbulence or under the vibration, there also the failure could happen because of fatigue. So, joints are designed so that fatigue failure does not happen for the life cycle of the joint for which it is designed.



Then it is important to understand the failure modes of the joints, common failure modes. I am talking about fatigue, I am talking about creep. Generally, fracture, fatigue, shear are the modes of joint failure. Fracture occurs when a joint experiences a sudden break due to exceeding materials ultimate strength that is exact fracture directly the fracture has happened the testing that we witnessed in the previous lectures. So, you saw how the fracture happens.

Fatigue is progressive damage caused by cyclic loading leading to crack initiation and propagation. Shear happens when forces act parallel to the joint causing one part to slide over, another example for the fracture is a welding bridge joint fracturing under excessive load. Example for the fatigue failure is aircraft rivets as I mentioned that develop fatigue cracks due to repeated pressurization cycles. For the shear example that could be quoted is rivets in metal structure shearing off under extreme Wind loads.



I will just discuss two case studies and close this lecture. There was a collapse of Silver Bridge in 1967. The overview. The Silver Bridge connecting Point Pleasant, West Virginia to Gallipoli's OEO collapsed on December 15, 1967 leading to deaths of 46 people. The cause.

Failure was traced to a fatigue fracture in an eyebar joint, especially eyebar 330. The bridge design used eyebar chains where each link carried the bridge's load. A small crack developed over years due to repeated stress, that is cyclic loading, and was further worsened by corrosion. The crack grew until it caused a catastrophic brittle fracture. So, corrosion is the factor here because bridges are built on the water and water is generally salt water. And salt water leads to or enhances the corrosion. It generates or creates a corrosive environment.

Case Studies

Why It Failed: The bridge was built in 1928, and its eyebar design was susceptible to stress concentration at the pin connections. No redundancy existed in the design, meaning if one eyebar failed, the whole structure was compromised. Additionally, inadequate inspection methods at the time couldn't detect internal cracks, contributing to the disaster.

Key Lesson: The collapse highlighted the importance of redundancy in design and the need for regular inspection to detect fatigue cracks early, especially in critical joints.

https://www.wboy.com/wp-content/uploads/sites/43/2022/12/0b85a966-9089-b733-233b-999d138794b3.png?w=1280

Why it Failed? Bridge was built in 1928 and its eyebar design was susceptible to stress concentrations at the pin connections. No redundancy existed in the bridge design, meaning if one eyebar failed, the whole structure was compromised.

So redundancy or safety was not taken into account. Additionally, inadequate instruction methods at the time, couldn't detect internal cracks contributing to the disaster. Nowadays, we have sonar waves, radio waves to understand the internal defects as well. In those times, in 1967, those were not available. Key lesson, the collapse highlighted the importance of redundancy in design and the need for regular inspection to detect fatigue cracks early, especially in critical joints.

Case Studies

2. Aloha Airlines Flight 243 (1988)

Overview: On April 28, 1988, Aloha Airlines Flight 243 experienced explosive decompression while cruising at 24,000 feet, causing a large section of the fuselage to tear away. Remarkably, the aircraft landed safely, but one flight attendant was killed, and 65 passengers were injured.

Cause:

- The failure was due to **fatigue cracks** in the **riveted joints** of the fuselage. These cracks formed over time due to the aircraft's repeated pressurization and depressurization cycles, common in short-haul flights.
- The cracks initiated at **multiple rivet holes** and propagated, to form a large fracture.

https://im.indiatimes.in/content/2023/Nov/aloha-2_655cac2deca30.jpg?w=1200&h=900&cc=1&webp=1&q=75

Another case is here of the Aloha Airlines Flight 243 (1988). On April 28, 1988, Aloha Airlines flight 243 experienced explosive decompression while cruising at 24,000 feet. At this height, this caused a large section of the fuselage to tear away. Remarkably, the aircraft landed safely but one flight attendant was killed and 65 passengers were injured. So, this was the condition that is shown in the figure.

The failure was due to fatigue cracks in the riveted joints of the fuselage. These cracks formed over time due to aircraft's repeated pressurization and depressurization cycles common in short-haul flights. The cracks initiated at multiple rivet holes and those propagated to form a large fracture. So, also the corrosive salt water environment around the Hawaiian island accelerated the fatigue because around the Hawaiian island as a flight we used to land and the environment was again the corrosive salt water.

Case Studies

Why It Failed: The aircraft had been in service for over 19 years with around 89,680 flight cycles. During inspections, some fatigue damage was missed because older inspection techniques couldn't detect the extent of the internal damage in the lap joints.

Key Lesson: This incident emphasized the need for improved inspection methods, especially for aircraft operating in corrosive environments, and the importance of accounting for fatigue in joint design under cyclic loading conditions.

Conclusion: Both cases underscore the criticality of regular maintenance inspections, and designing for redundancy and fatigue resistance in permanent joints, especially in safety-critical applications.

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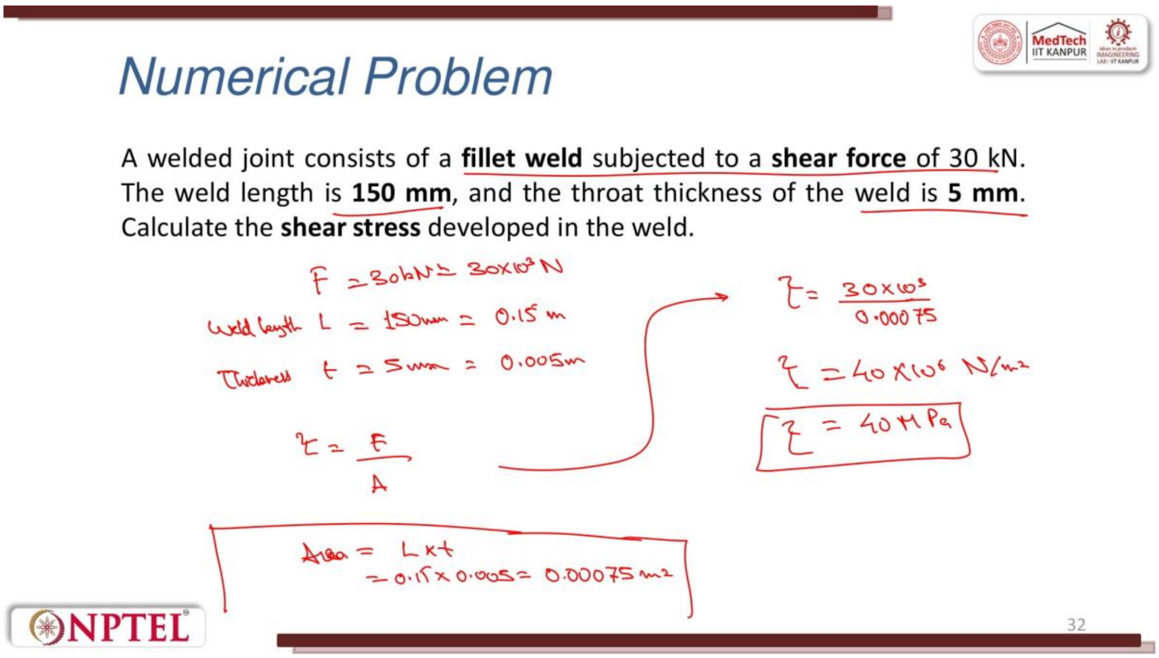
NPTEL

Why it failed? The aircraft had been in service for over 19 years with around 89,680 flight cycles. During inspections some fatigue damage was missed because older inspection techniques couldn't detect extent of internal damage. Internal damage seen welding joints or in the permanent joints how critical is the need to identify the damage that is internal. Key lesson, the incident emphasized the need for improved inspection method especially for aircraft operating in corrosive environments and the importance of accounting for fatigue in joint design under cycling loading conditions.

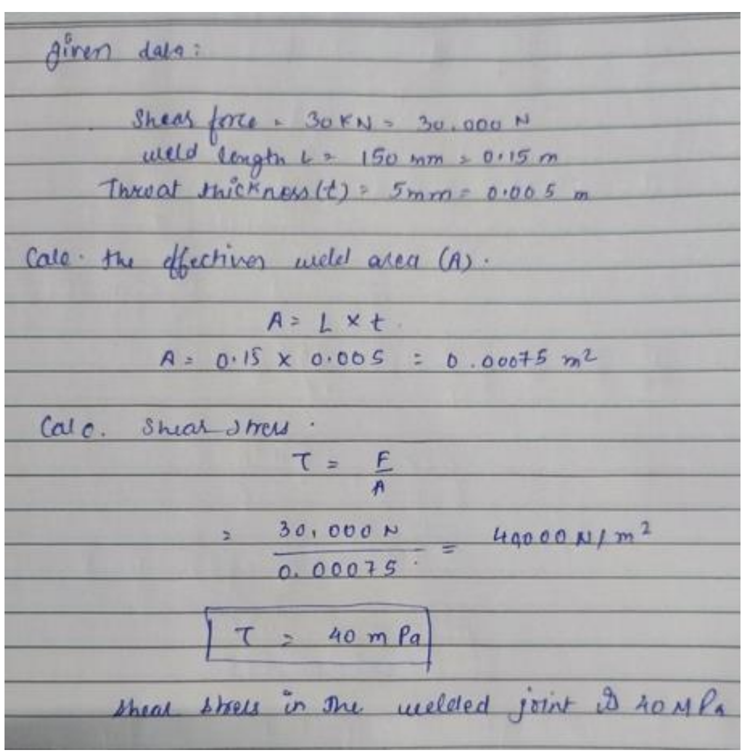
Conclusion, both cases underscore the criticality of regular maintenance, inspections, designing for redundancy and fatigue resistance in permanent joints, especially in safety critical applications. So, regular maintenance whatever we are working upon is important and when we design something for a life cycle within the life cycle, the periods or the preventive maintenance schedule is also provided. So, all the testing that we do is for a period. For this period, this would work.

So, it is important to have a regular maintenance whenever we are talking about any joints where the permanent or temporary permanent joints would have maintenance frequency lower than those are there in temporary joints. Temporary joint could loosen with small vibrations even.



A quick problem statement let us see on the welding joint. A welded joint consists of a fillet weld subjected to a shear force of 30 kilo Newton. The weld length is 150 millimeter and the throat thickness of the weld is 5 millimeter. Calculate the shear stress developed in the weld.

Solution:



Given data:

Shear force = 30 KN = 30,000 N

weld length L = 150 mm = 0.15 m

Throat thickness (t) = 5mm = 0.005 m

Calc. the effective weld area (A).

$$A = L \times t$$

$$A = 0.15 \times 0.005 = 0.00075\ m^2$$

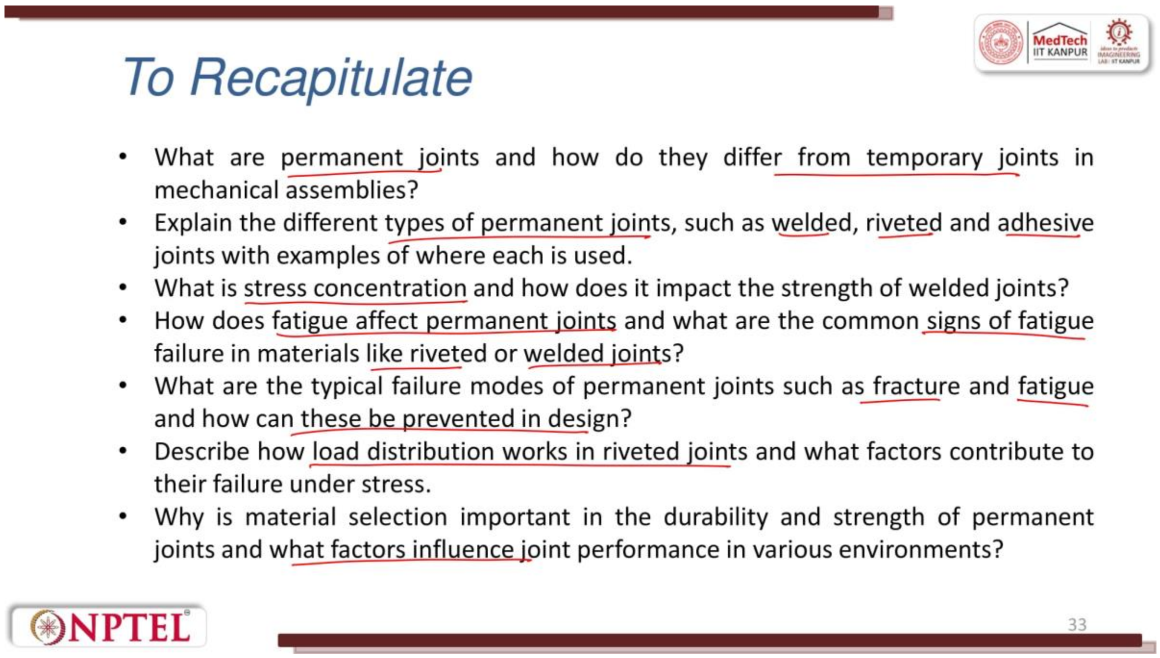
Calc. Shear stress.

$$\tau = \frac{F}{A}$$

$$= \frac{30,000\ N}{0.00075} = 40000\ N/m^2$$

$$\boxed{\tau = 40\ mPa}$$

Shear stress in the welded joint is 40 MPa



Just to recapitulate what we covered in this lecture. We talked about the permanent joints. The question is what are permanent joints and how they differ from temporary joints in mechanical assemblies.

Explain the different types of permanent joints such as welded, riveted or glued or adhesive joints with examples of where each is used. What is stress concentration and how does it impact the strength of welded joints? How does fatigue affect permanent joints and what are the common signs of fatigue? Common signs of fatigue failure in materials like riveted or welded joints. What are the typical failure modes of permanent joints such as fracture fatigue and how can these be prevented in design that is in design itself what steps do you take or what prevention do you keep so that these do not come.

Describe how load distribution works in riveted joints and what factors contribute to their failure under stress. Why is material selection important in the durability and strength of permanent joints? What factors influence joint performance in various environments? With this, this lecture is completed. And with two or three more lectures, I will complete the course.

Thank you.