



SNS COLLEGE OF TECHNOLOGY

Coimbatore-35
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DEPARTMENT OF MECHANICAL ENGINEERING

19MEZ405- CASTING DESIGN AND PERFORMANCE

IV YEAR / VIII SEM

UNIT V - CASTING PERFORMANCE



UNIT V CASTING PERFORMANCE



Cast iron is a group of iron-carbon alloys with a carbon content greater than 2%, and it is widely used in engineering applications due to its excellent castability and good machinability. However, cast irons, like other metals, are susceptible to corrosion when exposed to environmental factors such as moisture, oxygen, acids, and salts.

Types of Corrosion in Cast Iron

General Corrosion

Problem:

General corrosion occurs uniformly over the exposed surface of cast iron. This type of corrosion is often caused by exposure to water, atmospheric conditions, or acidic environments.

Causes:

Oxidation: Cast iron reacts with oxygen in the presence of moisture to form iron oxide (rust), which leads to the deterioration of the material.

Acidic Environments: Exposure to acids (like sulfuric acid) accelerates the breakdown of cast iron.

Solution:

Use **protective coatings** or **corrosion-resistant alloys**.

Implement **cathodic protection** and ensure proper drainage to avoid water accumulation.

Pitting Corrosion

Problem:

Pitting is a localized form of corrosion that leads to the formation of small pits or holes on the surface of cast iron.

Causes:

Occurs in the presence of **chlorides** (e.g., saltwater or deicing agents).

Oxygen availability: Areas with limited oxygen access may develop pitting corrosion due to localized electrochemical reactions.

Solution:

Apply **coatings** to protect exposed surfaces.

Use **alloying elements** like chromium or nickel to improve resistance.



Graphitization

Problem:

Graphitization occurs when the iron matrix of the cast iron transforms into graphite in the presence of corrosive elements, such as high temperatures or exposure to hydrogen.

Causes:

Exposure to elevated temperatures for prolonged periods.

Hydrogen-induced corrosion can lead to the formation of graphite at grain boundaries, weakening the material.

Solution:

Minimize **temperature fluctuations** in service environments.

Alloying elements like silicon and chromium can enhance resistance to graphitization.

Crevice Corrosion

Problem:

Crevice corrosion happens in narrow, confined spaces where water or corrosive agents can accumulate, such as joints, flanges, or beneath gaskets.

Causes:

Accumulation of **chlorides** or **acids** in tight spaces.

Lack of **oxygen** in confined areas leading to localized corrosion.

Solution:

Avoid creating **crevices** in design by using gaskets or seals made of corrosion-resistant materials.

Regular cleaning and inspection of critical areas.

Prevention and Protection Methods

Surface Coatings:

Applying protective coatings like **paint**, **epoxies**, or **galvanization** can significantly reduce corrosion by providing a barrier between the cast iron surface and the corrosive environment.



Cathodic Protection:

This technique involves applying a **sacrificial anode** to prevent the cast iron from corroding. The anode corrodes in place of the iron, thus protecting the structure.

Environmental Control:

Reducing exposure to moisture and aggressive chemicals can help extend the life of cast iron. For example, reducing the exposure to **chlorides** and **acidic environments** is particularly important.

Corrosion of Cast Carbon and Low-Alloy Steels

Cast carbon and low-alloy steels are widely used in structural and mechanical applications due to their strength and toughness.

Types of Corrosion in Cast Carbon and Low-Alloy Steels

General Corrosion

Problem:

Cast carbon steels are vulnerable to uniform corrosion, especially in **acidic or saline environments**. The material corrodes uniformly across the exposed surface.

Causes:

Oxidation due to exposure to moisture and oxygen.

Acidic environments (e.g., sulfuric acid or hydrochloric acid).

Solution:

Use **protective coatings** like **zinc** or **epoxy-based coatings**.

For some applications, use **corrosion-resistant steel alloys** (e.g., stainless steel).

Pitting Corrosion

Problem:

Pitting is a localized form of corrosion that leads to the formation of pits or holes, often seen in low-alloy steels exposed to chloride solutions or saltwater.

Causes:

Chlorides present in seawater or road salts accelerate pitting.



Crevice Corrosion

Problem:

This occurs in confined spaces where **water** or **corrosive agents** accumulate, such as under bolts, washers, or gaskets.

Causes:

Chlorides or **acids** trapped in confined areas.

Lack of **oxygen** or limited flow in tight spaces.

Solution:

Design components to avoid tight crevices.

Apply **sealants** or **gaskets** made of corrosion-resistant materials.

Galvanic Corrosion

Problem:

When cast carbon or low-alloy steel is in contact with a more noble metal (such as brass, copper, or stainless steel), galvanic corrosion can occur, where the steel corrodes preferentially.

Causes:

Contact with **dissimilar metals** in an electrolyte, resulting in an electrochemical reaction.

Solution:

Isolate dissimilar metals using coatings or non-conductive materials.

Use sacrificial anodes made of more reactive materials like **zinc** or **magnesium**.

High-Temperature Corrosion

Problem:

Exposure to elevated temperatures (e.g., in industrial furnaces or engines) can lead to the formation of oxides or other corrosive products, weakening the material.

Causes:

Oxidation at high temperatures.

Reaction with gases such as **sulfur dioxide** or **nitrogen oxides** in combustion gases.

Solution:

Use **heat-resistant alloys** or **protective coatings** to prevent oxidation.

Control temperature and exposure times to minimize high-temperature corrosion.



Prevention and Protection Methods

Surface Treatments:

Apply **protective coatings** like **zinc**, **paint**, or **epoxies** to prevent direct exposure to corrosive agents.

Use **passivation** techniques (such as **chromate conversion coatings**) to form a protective oxide layer on the steel surface.

Alloying Elements:

Add **chromium**, **molybdenum**, or **nickel** to the steel to improve its resistance to corrosion. Low-alloy steels containing these elements (like **weathering steel**) are less prone to atmospheric corrosion.

Cathodic Protection:

Similar to cast iron, applying **sacrificial anodes** or using **impressed current cathodic protection** can help prevent corrosion in cast carbon or low-alloy steels.

Environmental Control:

Minimize exposure to harsh environments, such as reducing exposure to **chlorides**, **sulfur compounds**, and **acids**. Regular cleaning and maintenance are critical to extend the life of steel components.

Regular Maintenance and Inspection:

Regular inspection for signs of corrosion (like rust formation, pitting, or discoloration) and timely repairs or replacements can prevent severe damage.



Design Problems Involving Unequal Section



Cast stainless steels are alloys that contain iron, chromium (at least 10.5%), and varying amounts of other alloying elements, such as nickel, molybdenum, and manganese. These steels are widely used in applications where corrosion resistance is crucial, such as in chemical processing, food production, and marine environments. Despite their excellent corrosion resistance, cast stainless steels can still suffer from various forms of corrosion, particularly when exposed to harsh or aggressive environments.

Types of Corrosion in Cast Stainless Steels

General Corrosion

Problem:

General corrosion occurs uniformly over the exposed surface of stainless steel. Although stainless steel resists this form of corrosion much better than carbon steels, it can still happen when the protective chromium oxide layer is damaged or overwhelmed by aggressive environments.

Causes:

Exposure to **chlorides**, **acids**, and **moisture**.

High temperatures or **oxidizing conditions** can degrade the chromium oxide film.

Solution:

Use **higher alloy grades** like **duplex stainless steels** or **super-austenitic stainless steels**.

Apply **protective coatings** or **passivation treatments** to reinforce the chromium oxide layer.

Ensure proper **design** to avoid stagnation or pooling of corrosive media.



Design Problems Involving Unequal Section



Crevice Corrosion

Problem:

Crevice corrosion occurs in narrow gaps or crevices where the flow of oxygen is restricted. This can lead to the localized breakdown of the protective oxide layer, particularly in marine or acidic environments.

Causes:

Stagnant solutions trapped in crevices or under seals.

Chlorides and **acids** in confined spaces can lead to localized acidification, resulting in accelerated corrosion.

Solution:

Minimize **crevices** in the design, or use **gaskets** and **seals** that resist corrosion.

Use **welds** that are well-polished and ensure **even surface finishes** to reduce corrosion-prone areas.

Electropolishing can help remove material from tight areas and reduce the risk of crevice corrosion.

Stress Corrosion Cracking (SCC)

Problem:

Stress corrosion cracking (SCC) is the growth of crack formations in a material caused by the combined influence of tensile stress and a corrosive environment. This can be particularly dangerous for cast stainless steels under certain conditions.

Causes:

Exposure to **chlorides** (such as in seawater or deicing salts) under **tensile stress**.

Susceptibility increases with **high temperatures** and **high-strength alloys**.

Solution:

Use **low-carbon grades** or **stabilized grades** like **321** or **347 stainless steel**, which are less prone to SCC.

Ensure that components are **stress-relieved** during manufacturing and avoid high-stress concentrations in the design.

Environmental control, such as limiting exposure to chlorides or reducing tensile stresses, can also help reduce SCC.



Design Problems Involving Junctions in Casting



Intergranular Corrosion (Sensitization)

Problem:

Intergranular corrosion occurs at the grain boundaries of stainless steel, often after it has been exposed to high temperatures. The high-temperature exposure causes the formation of **chromium carbides**, which depletes chromium from the adjacent areas, making them more susceptible to corrosion.

Causes:

Welding, heat treatment, or prolonged exposure to temperatures between 450–850°C (832–1562°F) can lead to chromium carbide precipitation.

The reduction of chromium at grain boundaries reduces the steel's corrosion resistance in those areas.

Solution:

Use **low-carbon alloys** such as **304L** or **316L**, which reduce carbide formation.

Choose **stabilized alloys**, like **321** or **347 stainless steel**, which contain **titanium** or **niobium** to prevent carbide precipitation.

If welding is necessary, use **welding rods** with a low carbon content to avoid sensitization.

Galvanic Corrosion

Problem:

When cast stainless steel comes into contact with a more noble metal (e.g., brass or copper), it may suffer galvanic corrosion, where the stainless steel acts as the anode and corrodes preferentially.

Causes:

Contact between **stainless steel** and a **more noble material** in an electrolyte, such as seawater.

Differences in the **electrochemical potential** between metals can lead to accelerated corrosion of the less noble material.

Solution:

Insulate dissimilar metals to prevent direct contact.

Apply **sacrificial anodes** made from more active metals (e.g., zinc) to protect the stainless steel.

Use **corrosion-resistant alloys** for both metals to minimize the risk of galvanic corrosion.



Design Problems Involving Junctions in Casting



High-Temperature Corrosion

Problem:

Cast stainless steels exposed to high-temperature environments, such as in furnaces or exhaust systems, can experience high-temperature corrosion, especially if they are exposed to **sulfur compounds**, **sulfur dioxide**, or **oxidizing gases**.

Causes:

Oxidation at high temperatures can lead to the formation of **iron oxides** or **chromium oxide** layers, which deteriorate the material.

Exposure to **sulfur** or **phosphorus** can result in the formation of **sulfide films** that weaken the material.

Solution:

Use **heat-resistant stainless steels** that contain additional elements like **molybdenum** or **silicon** to enhance high-temperature resistance.

Apply **protective coatings** such as **aluminizing** or **ceramic coatings** to reduce oxidation and increase durability.



Design Problems Involving Junctions in Casting



Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. Cast iron's ability to withstand fatigue depends on several factors, such as its microstructure, casting quality, and the type of loading applied.

Key Factors Influencing Fatigue Performance:

Microstructure:

The microstructure of cast iron plays a significant role in its fatigue properties. Different types of cast iron, such as **gray cast iron**, **ductile cast iron**, and **white cast iron**, exhibit different fatigue behaviors.

Gray Cast Iron:

Gray cast iron has a graphite flake structure that acts as stress concentrators and can lead to crack initiation. However, the graphite flakes also help to dissipate stresses, which can make gray cast iron more resistant to crack propagation under certain conditions.

Ductile Cast Iron (Nodular Cast Iron):

Ductile cast iron, which contains spheroidal graphite, generally exhibits better fatigue resistance than gray cast iron. The rounder graphite shape reduces stress concentration, allowing for better load distribution and crack resistance. This makes ductile cast iron suitable for components that are subjected to high cyclic stresses.

White Cast Iron:

White cast iron, characterized by a hard matrix with cementite (Fe_3C), is very brittle and has poor fatigue resistance compared to gray and ductile cast iron. It tends to crack and fail under repeated loading.



Design Problems Involving Junctions in Casting



Graphite Structure and Size:

In gray cast iron, the size and distribution of graphite flakes play a crucial role in determining fatigue strength. Coarse, irregularly shaped graphite flakes act as stress concentrators and reduce fatigue strength, while fine, uniformly distributed graphite can improve fatigue resistance.

Casting Defects:

The presence of defects like porosity, shrinkage, and micro-cracks can significantly reduce the fatigue strength of cast iron. High-quality casting with fewer defects leads to better fatigue performance.

Alloying Elements:

Certain alloying elements, such as **manganese**, **silicon**, and **nickel**, can improve the fatigue properties of cast iron by refining the microstructure and enhancing its strength. For example, **manganese** helps to stabilize the graphite and improve tensile strength, while **silicon** enhances the hardness and wear resistance of cast iron.

Surface Finish:

The surface finish of cast iron components also affects their fatigue strength. A rough surface with high surface roughness or defects can serve as crack initiation sites, leading to premature fatigue failure. **Shot peening** or **surface hardening** processes can improve surface integrity and increase fatigue life.

Fatigue Life and Endurance Limit:

Endurance Limit: Cast irons typically exhibit an endurance limit, which is the maximum stress below which a material can withstand an infinite number of stress cycles without failing. The endurance limit varies based on the type of cast iron and the specific application. **Ductile cast iron** has a higher endurance limit compared to **gray cast iron**, due to its superior ductility and crack resistance.

S-N Curve: The **S-N (stress-number of cycles)** curve, also known as the fatigue life curve, describes the relationship between the applied stress and the number of cycles a material can withstand before failure. Cast iron components subjected to cyclic loading typically exhibit a **low-cycle fatigue** behavior at high stresses and **high-cycle fatigue** at lower stresses.

Fracture Properties of Cast Irons

Fracture behavior refers to how a material responds to stress and whether it undergoes catastrophic failure (fracture) under certain loading conditions. Cast iron's fracture properties are influenced by its **brittleness**, **strength**, and **toughness**.



Design Problems Involving Junctions in Casting



Fracture Mechanisms:

Gray Cast Iron:

Gray cast iron is generally **brittle** and fractures in a **brittle manner** under tensile stress. The **graphite flakes** in the microstructure act as **crack initiation sites**, and the material typically fails by the formation of **microcracks** that propagate through the material. Despite this, gray cast iron can still handle some level of stress due to its ability to resist compressive loads.

Mode I Fracture (Tensile Fracture): In gray cast iron, fractures often initiate at the graphite flakes, and crack propagation follows the path of least resistance, leading to a brittle, **transgranular fracture**.

Mode II and Mode III Fracture: These are **shear fractures** that occur when the material is subjected to a shear force. Although less common in gray cast iron, shear failure can occur when the material is subjected to bending or torsion.

Ductile Cast Iron:

Ductile cast iron, which contains spheroidal graphite, exhibits improved fracture toughness compared to gray cast iron. The **nodular graphite** particles act as **crack deflectors**, reducing the likelihood of crack propagation. Ductile cast iron is more likely to fail by **ductile fracture** (with significant plastic deformation) rather than brittle fracture.

Ductile Fracture: In ductile cast iron, fracture often occurs via a **cup-and-cone** fracture mode, where the material undergoes significant plastic deformation before failure. The spherical graphite inclusions help to absorb energy and prevent crack propagation.

White Cast Iron:

White cast iron is very hard and brittle and has poor fracture toughness. Fractures in white cast iron typically occur due to **brittle fracture** under tensile stress. The high hardness of white cast iron makes it vulnerable to crack initiation, and once a crack forms, it propagates rapidly.

Fracture Toughness:

Gray Cast Iron:

Gray cast iron has relatively **low fracture toughness**, primarily due to the presence of graphite flakes, which act as natural flaws in the material. These flaws make it prone to crack propagation under stress, especially under tensile loading.

Ductile Cast Iron:

Ductile cast iron exhibits higher fracture toughness compared to gray cast iron due to its more uniform microstructure. The presence of spheroidal graphite significantly improves the material's ability to absorb energy and resist crack propagation, resulting in a material that is less prone to catastrophic failure.

White Cast Iron:

White cast iron is the most brittle among the cast iron types, exhibiting poor fracture toughness. It fails easily under both tensile and impact loading.