Hull construction, alu, steel

Nov 2022

4. With reference to the attachment of aluminium superstructures to a steel hull:

(a) explain why it is not normal practice to join the two components using conventional welding techniques; (2)

(b) state the particular problems associated with the aluminium superstructure where it is bonded to a steel hull; (2)

(c) outline the maintenance that should be carried out to ensure the continued structural integrity of the vessel; (2)

(d) sketch a typical transition joint that could be utilised to attach an aluminium superstructure to a steel hull. (4)

June 2019

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(d) sketch a typical transition joint that could be utilised to attach an aluminium superstructure to a steel hull. (4)

Here is some information that may help you answer the question:

- Conventional welding techniques are not normally used to join aluminium superstructures to steel hulls because of the different properties of the two metals. Steel has a higher melting point than aluminium, so when the two metals are welded together, the aluminium can melt before the steel, resulting in a weak joint. Additionally, steel is more prone to rust than aluminium, and the heat from welding can accelerate the corrosion process.
- The particular problems associated with an aluminium superstructure bonded to a steel hull include:
    - Galvanic corrosion: This type of corrosion occurs when two dissimilar metals are in contact with each other in the presence of an electrolyte (such as seawater). The electricity from the steel hull can flow to the aluminium superstructure, causing the aluminium to corrode.
    - Stress corrosion cracking: This type of cracking can occur in aluminium alloys that are subjected to stress and a corrosive environment. The stress can come from the weight of the superstructure, or from the waves and wind.
    - Fatigue: Aluminium is more susceptible to fatigue than steel, so the superstructure is more likely to crack under repeated loading.

- The maintenance that should be carried out to ensure the continued structural integrity of the vessel includes:
  - Regularly inspecting the joints between the superstructure and the hull for signs of corrosion or cracking.
  - Maintaining the protective coatings on both the steel and aluminium.
  - Monitoring the stress levels in the superstructure and taking steps to reduce them if necessary.
- A typical transition joint that could be used to attach an aluminium superstructure to a steel hull is a bolted joint. Bolted joints are strong and can be easily inspected and maintained. They also help to isolate the two metals from each other, which can reduce the risk of galvanic corrosion.

March 2022

4. State, with reasons, a different welding/brazing/soldering process that is best suited to effect EACH of the following situations:

(a) joining two lengths of aluminium bronze seawater pipe, both pipes having the same diameter; (2)

(b) attaching a stainless steel handrail to a steel hull; (2)

(c) re-attach a section of broken flange on a cast iron pump casing; (2)

(d) attaching a brass flange onto a stainless steel pipe; (2)

(e) attaching a 1.0 mm steel section to 10 mm thick deckhead plate. (2)

Nov 2020

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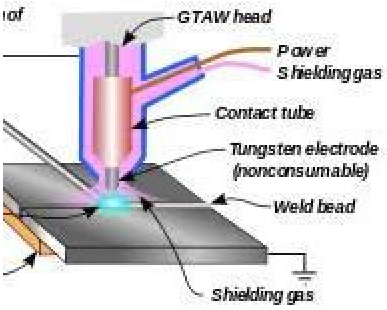
(a) Joining two lengths of aluminum bronze seawater pipe, both pipes having the same diameter.

The best process for this situation is gas tungsten arc welding (GTAW), also known as TIG welding. TIG welding is a precise and controlled process that is well-suited for joining thin materials, such as aluminum bronze. It is also resistant to corrosion, which is important for seawater pipes.



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en.wikipedia.org

Gas tungsten arc welding (GTAW)

(b) Attaching a stainless steel handrail to a steel hull.

The best process for this situation is shielded metal arc welding (SMAW), also known as stick welding. SMAW is a versatile process that can be used to join a variety of metals, including steel and stainless steel. It is also a relatively inexpensive and portable process, which makes it a good choice for shipboard repairs.

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fractory.com

Shielded metal arc welding (SMAW)

(c) Re-attaching a section of broken flange on a cast iron pump casing.

The best process for this situation is brazing. Brazing uses a filler metal that has a lower melting point than the base metals. This allows the filler metal to melt and flow into the joint, without melting the base metals. Brazing is a good choice for cast iron because it is less likely to cause cracking.

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brighton-science.com

Brazing

(d) Attaching a brass flange onto a stainless steel pipe.

The best process for this situation is silver soldering. Silver solder is a type of solder that has a high melting point and is very strong. It is a good choice for joining dissimilar metals, such as brass and stainless steel.

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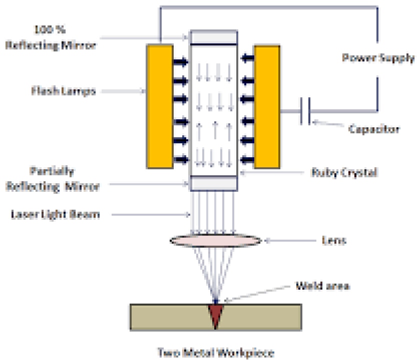
www.halsteadbead.com

Silver soldering

(e) Attaching a 1.0 mm steel section to 10 mm thick deckhead plate.

The best process for this situation is laser beam welding. Laser beam welding is a high-energy process that can create very strong and narrow welds. It is a good choice for this situation because it can weld the thin steel section to the thicker deckhead plate without melting too much of either metal.



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www.zillionsbuyer.com

Laser beam welding

Feb 2023

4. With reference to joining a steel hull to an aluminium superstructure:

(a) explain, with the aid of a sketch, the process of *explosion welding*; (6)

(b) explain why this joint is superior to an insulated bolt joint. (4)

The image you sent me shows a diagram of the explosion welding process, which is a method of joining dissimilar metals, such as steel and aluminum, together. In this process, one metal plate is propelled at high velocity towards another metal plate by an explosive detonation. The impact of the collision creates a bond between the two metals.

Explosion welding is a superior method to using insulated bolt joints for joining steel and aluminum for several reasons. First, explosion welding creates a continuous bond between the two metals, whereas an insulated bolt joint leaves a gap between the metals. This gap can create a weak spot in the joint, and it can also allow for the ingress of moisture and other corrosive elements.

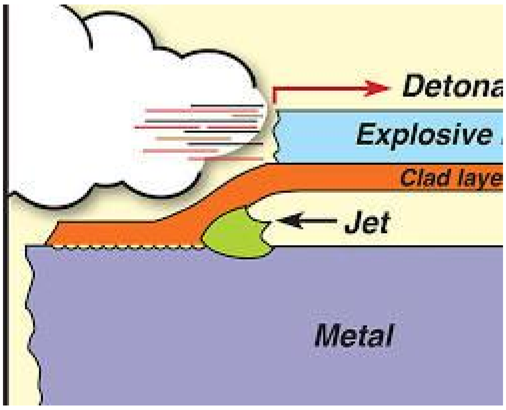
Second, explosion welding does not require the use of any fasteners, which can be a source of corrosion and fatigue. Third, explosion welding can be used to join metals of different thicknesses, whereas insulated bolt joints are typically limited to joining metals of the same thickness.

Finally, explosion welding can create a joint that is stronger than the base metals themselves. This is because the high velocity impact of the collision creates a metallurgical bond between the two metals.

Of course, there are also some disadvantages to explosion welding. First, it is a relatively expensive process. Second, it can be difficult to control the quality of the weld. And third, it can only be used to join simple shapes.

Overall, explosion welding is a versatile and effective method for joining dissimilar metals. It is a good choice for applications where a strong, corrosion-resistant bond is required.

Here is a sketch of the explosion welding process:



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fastenerengineering.com

Explosion welding sketch

March 2022

1. (a) Outline THREE disadvantages of using aluminium in vessel construction. (3)

   (b) Outline THREE advantages of using steel in vessel construction. (3)

   (c) Outline FOUR conditions necessary in the preparation of steel surfaces prior to painting, to ensure a good surface finish. (4)

Nov 2019

1. (a) Outline THREE disadvantages of using aluminium in vessel construction. (3)

   (b) Outline THREE advantages of using steel in vessel construction. (3)

   (c) Outline FOUR conditions necessary in the preparation of steel surfaces prior to painting, to ensure a good surface finish. (4)

Nov 2018

2. (a) Outline THREE disadvantages of using aluminium in vessel construction. (3)

   (b) Outline THREE advantages of using steel in vessel construction. (3)

   (c) Outline FOUR conditions necessary in the preparation of steel surfaces prior to painting, to ensure a good surface finish. (4)

1. Outline three disadvantages of using aluminum in vessel construction.
2. Outline three advantages of using steel in vessel construction.
3. Outline four conditions necessary in the preparation of steel surfaces prior to painting, to ensure a good surface finish.

I can help you brainstorm some ideas for each of these questions, but ultimately the best answers will depend on the specific context of the assignment. For example, the relative importance of different factors (such as cost, weight, or strength) may vary depending on the type of vessel being built.

Here are some general ideas to get you started:

Disadvantages of using aluminum in vessel construction:

- Higher cost: Aluminum is generally more expensive than steel, which can be a major disadvantage for large vessels.
- Lower strength: Aluminum is not as strong as steel, so it may not be suitable for all applications. For example, it may not be strong enough to withstand the forces of heavy seas or ice.
- More difficult to weld: Aluminum can be more difficult to weld than steel, which can increase the cost and complexity of construction.

Advantages of using steel in vessel construction:

- Lower cost: Steel is generally less expensive than aluminum, which can be a major advantage for large vessels.
- Higher strength: Steel is stronger than aluminum, so it is better suited for applications where strength is important.
- Easier to weld: Steel is easier to weld than aluminum, which can reduce the cost and complexity of construction.

Conditions necessary for preparing steel surfaces prior to painting:

- Surface must be clean and free of dirt, grease, and oil. This is essential for ensuring that the paint adheres properly to the steel.
- Surface must be rough enough to provide a good "tooth" for the paint. This can be achieved by sandblasting or other methods.
- Surface must be dry. Moisture can prevent the paint from adhering properly.
- Steel must be at the correct temperature. Painting should not be done if the steel is too hot or too cold.

May 2023

1. With reference to carbon fibre used in marine construction:

(a) describe the properties that make it suitable for EACH of the following:

(i) hull construction; (2)

(ii) mast construction; (2)

(b) explain its undesirable properties for the applications in part (a); (3)

(c) explain the safety considerations necessary when working with carbon fibre. (3)

Part (a): Describing the properties of carbon fiber for hull and mast construction

- Hull construction:
  - High strength-to-weight ratio: Carbon fiber is incredibly strong for its weight, making it ideal for building lightweight hulls that can withstand the stress of waves and currents. This can improve a vessel's fuel efficiency and performance.
  - Corrosion resistance: Carbon fiber is highly resistant to corrosion from saltwater and other marine environments, unlike metals like steel which can rust and deteriorate. This reduces maintenance costs and extends the lifespan of the hull.
  - Stiffness and dimensional stability: Carbon fiber composites have minimal thermal expansion and contraction, helping the hull maintain its shape and integrity even in changing temperatures.
-
- Mast construction:
  - High stiffness and low weight: These properties allow for taller and lighter masts that can carry more sail area without bending excessively. This can improve a vessel's sailing performance and stability.
  - Fatigue resistance: Carbon fiber masts can withstand repeated cycles of stress without breaking, making them ideal for long voyages and harsh conditions.
  - Improved sail control: The stiffness of carbon fiber masts provides a more responsive feel to the sails, giving the crew greater control over the vessel.
-

Part (b): Explaining the undesirable properties of carbon fiber for marine applications

- High cost: Carbon fiber is significantly more expensive than traditional materials like fiberglass or wood, making it a less economical choice for some applications.
- Brittle failure: While strong, carbon fiber can be brittle and prone to catastrophic failure if damaged. This can be a safety concern, especially for high-performance vessels.
- Repair difficulty: Repairing damage to carbon fiber can be complex and expensive, requiring specialized training and materials.

Part (c): Explaining safety considerations when working with carbon fiber

- Sharp fibers: Carbon fibers can be sharp and cause skin irritation or even puncture wounds if handled improperly. Proper personal protective equipment (PPE) like gloves and long sleeves is essential when working with carbon fiber.
- Dust hazard: Cutting or sanding carbon fiber releases dust particles that can be harmful if inhaled. Proper ventilation and respiratory protection are necessary to avoid health risks.
- Galvanic corrosion: When combined with metals, carbon fiber can create galvanic corrosion, which can damage both materials. Careful selection of compatible materials and proper insulation are necessary to prevent this.

March 2021

1. With reference to the manufacture of carbon fire components:

(a) describe EACH of the following processes and its advantages:

(i) vacuum bagging; (2)

(ii) autoclave curing; (2)

(iii) resin transfer moulding; (3)

(b) list the type of component that EACH process described in part (a) is best suited to. (3)

three different composite fabrication processes: vacuum bagging, autoclave curing, and resin transfer molding (RTM). Each process has its own advantages and disadvantages, and is best suited for different types of components.

Here's a breakdown of each process:

Vacuum bagging:

- Process: A dry fiber preform is placed in a mold, and then covered with a vacuum bag. The air is evacuated from the bag, which applies pressure to the preform and forces the resin to flow through it. The part is then cured under heat.
- Advantages:
    - Simple and relatively inexpensive process.
    - Can be used with a wide variety of mold materials and shapes.
    - Good for producing parts with a high fiber volume fraction.
-
- Disadvantages:
    - Limited to parts with simple geometries.
    - Voiding (air pockets) can be an issue.
    - Not suitable for high-performance applications.
-

Autoclave curing:

- Process: The vacuum-bagged part is placed in an autoclave, which is a pressure vessel that can be heated and pressurized. The pressure helps to consolidate the laminate and eliminate voids.
- Advantages:
  - Produces high-quality parts with excellent surface finish and low void content.
  - Suitable for complex geometries and high-performance applications.
-
- Disadvantages:
  - Expensive process due to the high cost of autoclaves.
  - Limited throughput due to the long cycle times.
  - Not suitable for large parts.
-

Resin transfer molding (RTM):

- Process: The dry fiber preform is placed in a closed mold, and then resin is injected into the mold under pressure. The part is then cured under heat.
- Advantages:
  - Can produce high-quality parts with good surface finish and low void content.
  - Faster cycle times than autoclave curing.
  - Can be used for larger parts than vacuum bagging.
-
- Disadvantages:
  - More complex process than vacuum bagging.
  - Requires specialized molds and equipment.
  - Not suitable for all geometries.

Feb 2023

2. With reference to carbon fibre:

(a) describe how the base raw material is turned into a useable carbon fibre; (2)

(b) describe how the fibres produced in part (a) are turned into a usable product; (2)

(c) explain how its internal structure gives it its unique strength properties; (2)

(d) list FOUR properties of carbon fibre that make it desirable for marine fabrication. (4)

Part (a): Describing how the base raw material is turned into a usable carbon fiber

1. Precursor selection: The first step is to choose the right precursor material, which is typically PAN (polyacrylonitrile). PAN is a synthetic polymer that can be converted into carbon fiber through a high-temperature process.
2. Oxidation: The PAN precursor is then oxidized in air at temperatures between 200°C and 400°C. This process removes some of the hydrogen and nitrogen atoms from the PAN chains, making them more rigid and stable.

3. Carbonization: The oxidized PAN is then carbonized in an inert atmosphere at temperatures between 1000°C and 2000°C. This process drives off the remaining non-carbon atoms, leaving behind a highly ordered structure of carbon atoms.
4. Surface treatment: The carbon fibers are then treated with a sizing agent to improve their adhesion to resin and other materials.

Part (b): Describing how the fibers produced in part (a) are turned into a usable product

1. Layup: The carbon fibers are arranged in a mold or on a mandrel in the desired shape of the final product. This process is called layup.
2. Resin infusion or impregnation: Resin is then infused or impregnated into the fibers. This can be done through vacuum bagging, autoclave curing, or other techniques.
3. Curing: The resin is then cured, typically under heat and pressure. This process converts the resin from a liquid to a solid, binding the fibers together and forming the final composite product.
4. Finishing: The cured product may then be machined, painted, or coated to meet the specific requirements of the application.

Part (c): Explaining how the internal structure of carbon fiber gives it its unique strength properties

The unique strength of carbon fiber comes from its highly ordered internal structure. Each carbon fiber is made up of millions of carbon atoms arranged in a hexagonal lattice. This strong and stiff arrangement of atoms gives carbon fibers a very high tensile strength (strength under pulling forces) and a high modulus of elasticity (resistance to deformation).

In addition to its strong internal structure, carbon fiber is also very lightweight. This combination of high strength and low weight makes carbon fiber an ideal material for many marine applications, where weight savings and high performance are essential.

June 2019

6. With reference to in service defects found in glass reinforced plastic (GRP) hulls:

(a) state THREE possible causes of de-lamination; (3)

(b) describe TWO methods of detecting de-lamination in service; (2)

(c) describe TWO methods of repair to de-lamination on a sandwich construction hull; (2)

(d) list THREE design problems that can lead to stress cracking. (3)

Part (a): Causes of delamination

The question asks for three possible causes of delamination in GRP hulls. Here are three potential answers:

1. Stress on the hull: Physical stress on the hull can cause the layers of fiberglass and resin to separate. This can happen due to impact, grounding, or overloading.
2. Water ingress: If water gets into the laminate, it can weaken the bond between the layers and lead to delamination. This can happen through cracks in the gelcoat, poor sealing around fittings, or inadequate drainage.
3. Poor construction: Defects in the construction of the hull, such as voids in the laminate or improper curing of the resin, can also lead to delamination.

Part (b): Detecting delamination

The question asks for two methods of detecting delamination in service. Here are two options:

1. Tapping: Gently tapping on the hull with a mallet or other blunt object can produce a hollow sound if there is delamination beneath the surface.
2. Visual inspection: Looking for signs of cracking, bulging, or discoloration in the gelcoat can also indicate delamination.

Part (c): Repairing delamination on a sandwich construction hull

The question asks for two methods of repairing delamination on a sandwich construction hull. Here are two possibilities:

1. Vacuum injection: This technique involves injecting resin under pressure into the delaminated area to fill the voids and rebond the layers.
2. Grouting and re-laminating: This method involves removing the damaged material, filling the delaminated area with epoxy grout, and then re-laminating the surface.

Part (d): Design problems leading to stress cracking

The question asks for three design problems that can lead to stress cracking in GRP hulls. Here are three potential answers:

1. Sharp corners: Sharp corners in the hull design can create stress concentrations that make the material more susceptible to cracking.
2. Inadequate stiffening: If the hull is not properly stiffened, it can flex under load and develop cracks over time.
3. Discontinuities in the laminate: Holes, cutouts, or other discontinuities in the laminate can also create weak points where cracks are more likely to occur.

These are just some possible answers to the questions in the image. The specific causes, detection methods, and repair techniques for GRP hull defects will vary depending on the individual case.

Nov 2021

6. With reference to osmosis in glass reinforced plastic (GRP) hulls:

(a) explain how osmosis may be detected in service; (2)

(b) explain why simply drying out the hull is not a cure for the effects of osmosis; (2)

(c) describe the FULL process for the treatment of a hull suffering from the effects of osmosis. (6)

Part (a): How osmosis may be detected in service

Osmosis is a process where water diffuses through a semipermeable membrane from a less concentrated solution to a more concentrated one. In the case of GRP hulls, the semipermeable membrane is the gelcoat, and the more concentrated solution is the seawater outside the hull. This can cause the gelcoat to blister and delaminate.

Here are some ways to detect osmosis in service:

- Visual inspection: Look for blisters, cracks, or changes in the color or texture of the gelcoat.
- Tapping: Gently tap on the hull with a mallet or other blunt object. A hollow sound may indicate delamination beneath the surface.
- Moisture meter: Use a moisture meter to measure the moisture content of the hull. This can be a more quantitative way to detect osmosis.

Part (b): Why simply drying out the hull is not a cure for the effects of osmosis

Simply drying out the hull will not cure the effects of osmosis because it does not address the underlying cause of the problem, which is the presence of water trapped within the laminate. Once water has entered the laminate, it can react with the resin and cause it to break down. Even if the hull is dried out, the damage has already been done and the blisters and delamination will likely reappear.

Part (c): The FULL process for the treatment of a hull suffering from the effects of osmosis

The full process for treating a hull suffering from osmosis is a complex one and can vary depending on the severity of the damage. However, here are the general steps involved:

1. Cleaning and drying the hull: The hull must be thoroughly cleaned to remove any dirt, grime, or salt deposits. It should then be dried out completely, ideally using a combination of heat and ventilation.
2. Grinding: The blisters and any delaminated areas must be ground out to remove the damaged material.
3. Neutralizing the acids: The exposed laminate must be neutralized to remove any acidic salts that can cause further damage.
4. Filling and fairing: The ground-out areas must be filled with a suitable epoxy filler and faired smooth.
5. Re-laminating: A new layer of gelcoat or epoxy resin must be applied to the repaired areas.

6. Painting: The hull may need to be repainted to restore its appearance and protect it from further damage.

Part (d): The chemical reaction that occurs during osmosis

The chemical reaction that occurs during osmosis is complex, but it essentially involves the diffusion of water molecules through the gelcoat and into the laminate. The water molecules react with the resin in the laminate, causing it to break down and lose its strength. This can lead to the formation of blisters and delamination.

Nov 2022

6. With reference to osmosis in glass reinforced plastic (GRP) hulls:

(a) explain the process of osmosis and the method by which osmotic blisters occur in service; (6)

(b) describe a procedure for the local treatment of a single blister. (4)

Part (a): How water diffuses through the gelcoat

Water diffuses through the gelcoat via a process called osmosis. Here are the steps involved in this process:

1. Concentration gradient: There is a higher concentration of salt molecules in the seawater surrounding the boat hull compared to the inside of the hull. This creates a concentration gradient.
2. Semipermeable membrane: The gelcoat acts as a semipermeable membrane. This means that it allows water molecules to pass through, but it blocks the passage of salt molecules.
3. Diffusion: Water molecules move from the area of lower concentration (inside the hull) to the area of higher concentration (seawater) through the gelcoat. This movement is driven by the natural tendency of systems to equalize concentrations.

Part (b): Why blisters form on the hull surface

As water diffuses through the gelcoat and into the laminate, it can cause the resin in the laminate to break down. This breakdown process releases gases, which can create pockets or voids within the laminate. These pockets can eventually grow large enough to form blisters on the hull surface.

Part (c): How osmosis weakens the hull structurally

Osmosis weakens the hull structurally in a few ways:

- Gelcoat degradation: The gelcoat is the first line of defense against water intrusion. When it breaks down due to osmosis, it becomes less effective in protecting the laminate from further water ingress.

- Laminate degradation: As water diffuses into the laminate, it can cause the resin to break down and lose its strength. This can make the hull more susceptible to cracking and delamination.
- Blister formation: Blisters can weaken the hull by causing stress concentrations around them. Additionally, when blisters burst, they can leave large holes in the gelcoat that allow more water to enter the laminate.

Part (d): How osmosis can be prevented

There are a few things that can be done to prevent osmosis, such as:

- Using high-quality materials: Choosing a gelcoat and resin that are resistant to water absorption can help to slow down the osmosis process.
- Proper construction: Applying the gelcoat and resin correctly during construction is important to ensure that there are no gaps or voids that could allow water to enter.
- Maintaining the hull: Regularly cleaning and inspecting the hull for signs of damage can help to catch osmosis early and prevent it from causing serious damage.

6. With reference to the production of glass reinforced plastic (GRP) hulls:

   (a) describe the process of resin infusion moulding for the production of a hull; (4

   (b) state the advantages of resin infusion moulding with respect to traditional methods of construction; (3

   (c) explain how this process can virtually eliminate the onset of osmosis in the hull. (3

Nov 2023

- Preparation: The first step is to prepare the mold. This typically involves cleaning and waxing the mold to ensure a smooth finish.
- Layup: The dry glass fiber reinforcements are then placed in the mold. These reinforcements can be in the form of mats, woven fabrics, or unidirectional tapes.
- Resin infusion: The resin is then infused into the dry glass fibers. This can be done by gravity, but it is more common to use a vacuum to draw the resin through the fibers.
- Curing: Once the resin is infused, the mold is sealed and the resin is allowed to cure. This is typically done at an elevated temperature.
- Finishing: Once the resin is cured, the part can be removed from the mold and any finishing work can be done. This may include sanding, painting, or adding hardware.

Resin infusion molding has several advantages over traditional methods of GRP hull construction, such as hand layup and spray-up. These advantages include:

- Higher fiber-to-resin ratio: Resin infusion molding typically results in a higher fiber-to-resin ratio than other methods. This means that the hulls are stronger and lighter.
- Reduced void content: Resin infusion molding also reduces the void content in the laminate. Voids are air pockets that can weaken the laminate and make it more susceptible to water absorption.
- Improved surface finish: Resin infusion molding typically produces a better surface finish than other methods. This is because the resin is evenly distributed throughout the laminate.

- Reduced emissions: Resin infusion molding is a closed-mold process, which means that there are fewer emissions of Volatile Organic Compounds (VOCs) into the atmosphere.

Resin infusion molding can also virtually eliminate the onset of osmosis in the hull. Osmosis is a process that can cause blisters to form on the surface of the hull. It is caused by the diffusion of water through the hull and into the laminate. Resin infusion molding creates a denser laminate with fewer voids, which makes it less susceptible to osmosis.

Overall, resin infusion molding is a versatile and efficient process for producing high-quality GRP hulls. It is a good choice for boat builders who are looking for strong, lightweight, and durable hulls.

Feb 2023

6. With reference to glass reinforced plastic (GRP) hulls:

(a) state THREE causes for EACH of the following defects to occur:

(i) de-lamination; (3)

(ii) osmotic blisters; (3)

(iii) stress cracking; (3)

(b) state the part of the underwater section of the hull on which osmotic blisters most commonly occur. (1)