Quiz 1

Question 1

Flag question Marked out of 1 Not yet answered

What are some of your expectations from this course?

From this course, I hope to deep dive into material Properties, where I can gain a thorough understanding of the various properties of engineering materials, from mechanical, damage to thermal properties. Then, I can confidently evaluate and choose the right material for any project.

Besides, I want the course to offer practical exercises or projects that allow me to apply theoretical knowledge in real-world scenarios, helping me bridge the gap between theory and practice.

Finally, I'm eager to learn about the latest advancements in material science, such as nanomaterials, laminate composite and functionally graded materials, to constantly stay updated in mechanical engineering.

Question 2

Flag question Marked out of 1 Not yet answered

Choose a use case for a material, for example one of the parts of the standing rigging of a sailboat, where a new material enabled higher performance, and briefly explain how that material enabled higher performance compared to materials that were used earlier.

Example case: Laminated Lithium-Ion Batteries for Electric Vehicles (EVs)

Even though laminated batteries are still using lithium-ion based material, their new design has led to many novel applications. Normally, lithium-ion batteries usually have the cylindrical and prismatic designs. These designs are already carefully tested for the past decades and have been circulated in widespread applications for electronic devices. However, there exist many shortcomings in each design, such as packaging efficiency, suboptimal cooling rate and energy density [1]. Laminated batteries, on the other hand, have their cells stacked or folded into a flat, pouch-like shape. This design has gained significant attention, especially in the automotive industry for EV cars.

Performance Enhancement with Laminated Batteries compared to old designs [2]:

- Packaging Efficiency: The flat, rectangular shape of laminated batteries allows for more efficient packaging, maximizing the use of available space within an EV. Meanwhile, prismatic batteries are usually big and not packaging efficient.
- Improved Cooling: The design of laminated batteries allows for more uniform and efficient cooling. Cylindrical cells might not cool as evenly as laminate design
- Lightweight: The absence of metal casings, as seen in cylindrical cells, means laminated batteries can be lighter, which is crucial for EVs to minimize their weights.

Real-world Application: Nissan's electric Leaf vehicle uses a laminated lithium-ion battery pack [3]. The laminate battery design was chosen by Nissan for the above reasons, which helps enhance their vehicle's overall range and performance.

Sources:
[1] https://blog.epectec.com/pros-and-cons-of-lithium-prismatic-cells-vs-cylindrical-cells
[2] https://batteryuniversity.com/article/bu-301a-types-of-battery-cells
[3] https://www.marklines.com/en/report_all/rep1786_201811

Question 3

Flag question | Marked out of 1 | Not yet answered

In digital image correlation, a [deformation field] is iteratively applied to an image of a deformed object and numerically optimized, in order to minimize the [change in pixel intensities] relative to an image of the underformed object.

Quiz 2

Question 1

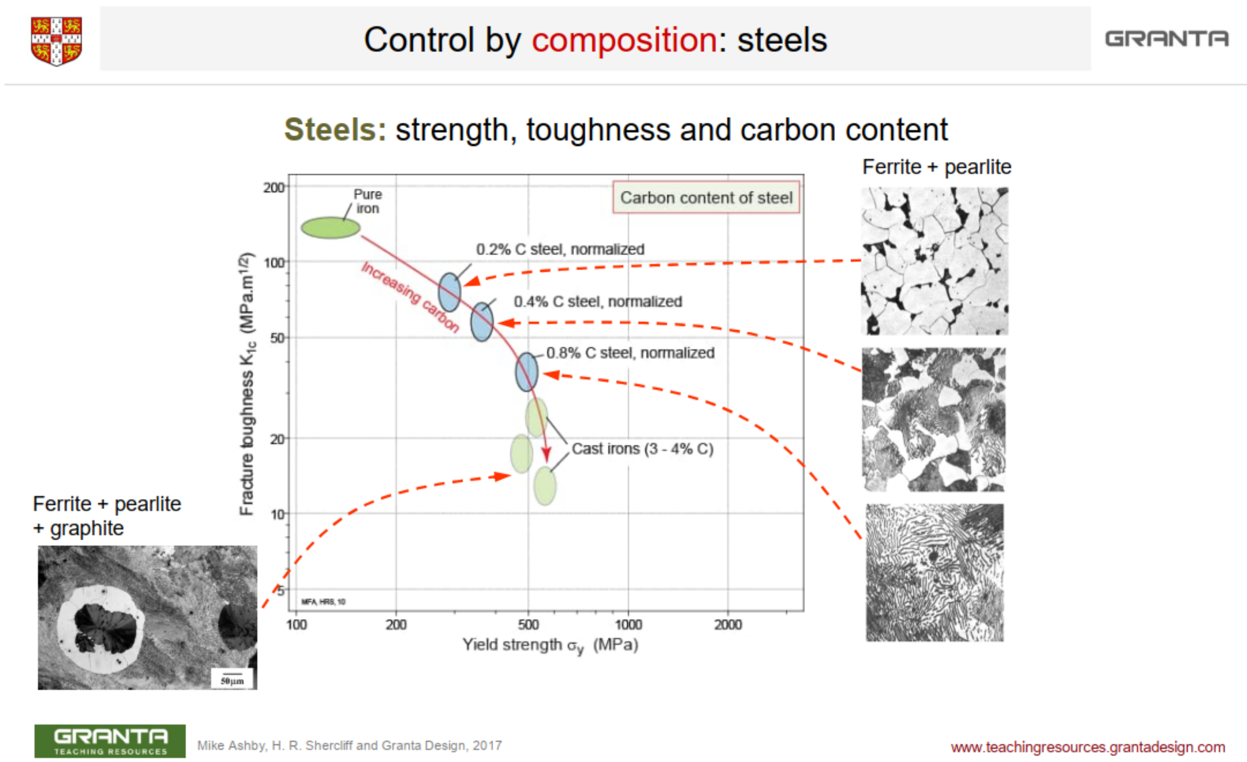
Flag question Marked out of 1 Not yet answered

When a low-carbon steel is austenitized and then slowly cooled to room temperature, the following phases are present:

Select one or more:

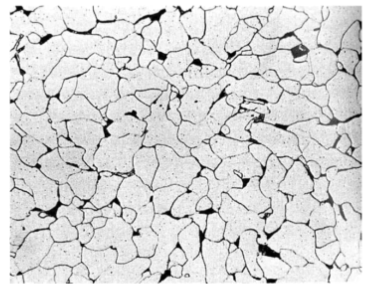
- ☐ a. carbon
- ☐ b. cementite
- ☑ c. pearlite
- ☑ d. ferrite
- ☐ e. austenite

Wrong answer. It should be pearlite, ferrite and cementite instead.

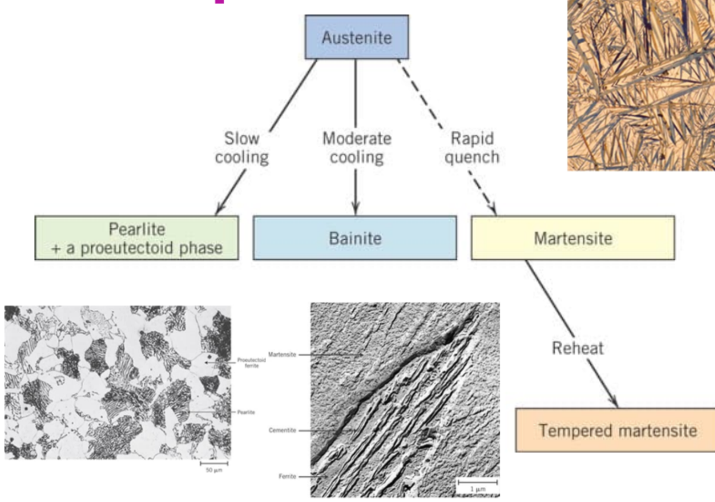


Basic low carbon steel

- C < 0.2 wt.%, Mn < 1.6 wt.%
- Strength (ys) 235-550 MPa, good elongation (25 %), toughness, formability and weldability
- Basic ferritic-pearlitic structural steel (e.g. S235, S355)
- Microstructure mainly ferritic with small amount of pearlite
- Steel structures, car sheet



Effect of cooling rate on austenite decomposition



Strength

martensite
tempered martensite
bainite
fine pearlite
coarse pearlite
spheroidite

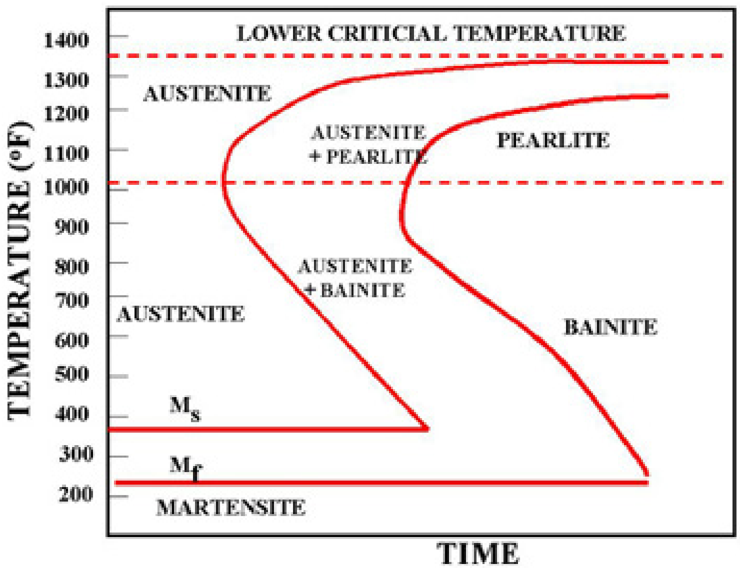
Ductility

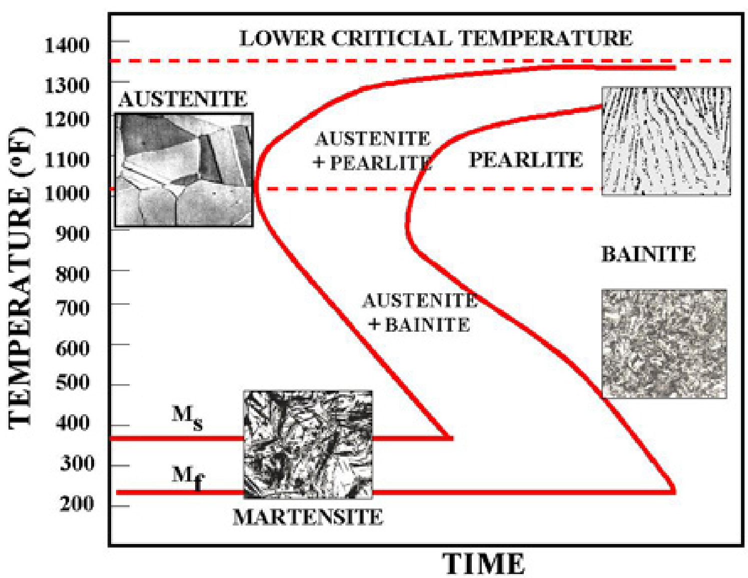
Question 2

Flag question Marked out of 1 Not yet answered

What is the difference between TTT and CCT diagrams?

TTT graph





https://www.metallurgyfordummies.com/time-temperature-transformation-ttt-diagram.html

TTT (Time-Temperature-Transformation) and CCT (Continuous Cooling Transformation) diagrams are used to illustrate the behavior of material transformation during cooling from a high temperature, typically from austenite above the low critical temperature line.

While TTT and CCT have both y-axis as Temperature (Linear) and x-axis as Time (Logarithmic), they differ in these aspects:

1. Transformation Interpretation:
TTT diagrams represent phase transformations that occur at constant temperatures (isothermal transformations). In other words, TTT diagram is only valid when the steel is cooled very rapidly to a certain temperature, then it is kept at constant temperature. Each phase combination where the horizontal line crosses is where the material turns into when it is heated at the correct amount of time from the x-axis. The phases where rapid cooling lines go through are not counted.

CCT diagrams depict phase transformations that happen during continuous cooling rate (for example: cooling from 700 to 400C from 10 seconds to 100 seconds) instead of rapid cooling and kept at constant temperature like TTT. Each phase combination where the vertical line with a certain slope crosses is where the material turns into when it is heated at the correct amount of time from the x-axis. The steeper the slope, the more rapid the cooling in CCT such as quenching in water.

2. Practical Relevance:

TTT diagrams are suited for theoretical knowledge of phase transformations where materials can be held isothermally.
CCT diagrams are more representative of real-world manufacturing processes where materials are continuously cooled.

This is because continuous cooling rate is much more easier to conduct than rapid cooling and kept at constant temperature

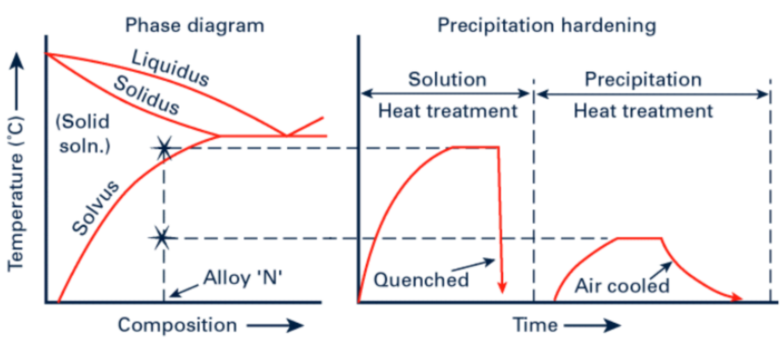
Question 3

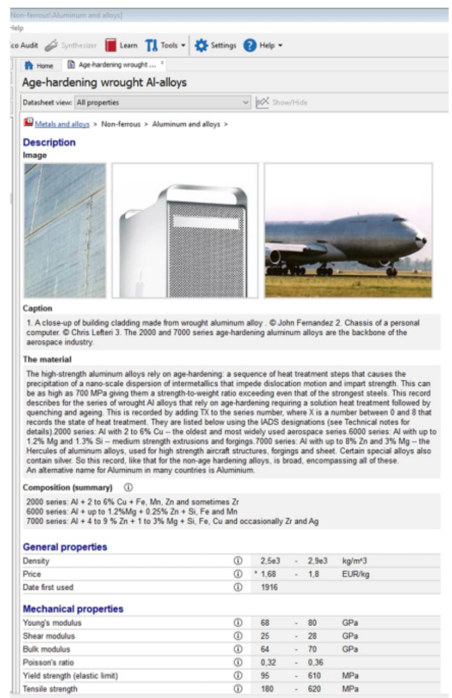
Flag question Marked out of 1 Not yet answered

What type of aluminum alloys are used in high-strength aircraft structures, and how are these alloys heat-treated?

Aluminum alloys

- **Age-hardening alloys**
  - 2000 series (Al-Cu)
  - 6000 series (Al-Mg-Si)
  - 7000 series (Al-Zn-Mg)





Non-ferrous\Aluminum and alloys]

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Home Age-hardening wrought ...

Age-hardening wrought Al-alloys

Datasheet view: All properties Show/Hide

Metals and alloys > Non-ferrous > Aluminum and alloys >

Description

Image

Caption

1. A close-up of building cladding made from wrought aluminum alloy . © John Fernandez 2. Chassis of a personal computer. © Chris Lefteri 3. The 2000 and 7000 series age-hardening aluminum alloys are the backbone of the aerospace industry.

The material

The high-strength aluminum alloys rely on age-hardening: a sequence of heat treatment steps that causes the precipitation of a nano-scale dispersion of intermetallics that impede dislocation motion and impart strength. This can be as high as 700 MPa giving them a strength-to-weight ratio exceeding even that of the strongest steels. This record describes for the series of wrought Al alloys that rely on age-hardening requiring a solution heat treatment followed by quenching and ageing. This is recorded by adding TX to the series number, where X is a number between 0 and 8 that records the state of heat treatment. They are listed below using the IADS designations (see Technical notes for details).2000 series: Al with 2 to 6% Cu -- the oldest and most widely used aerospace series.6000 series: Al with up to 1.2% Mg and 1.3% Si -- medium strength extrusions and forgings.7000 series: Al with up to 8% Zn and 3% Mg -- the Hercules of aluminum alloys, used for high strength aircraft structures, forgings and sheet. Certain special alloys also contain silver. So this record, like that for the non-age hardening alloys, is broad, encompassing all of these.
An alternative name for Aluminum in many countries is Aluminium.

Composition (summary)

2000 series: Al + 2 to 6% Cu + Fe, Mn, Zn and sometimes Zr
6000 series: Al + up to 1.2%Mg + 0.25% Zn + Si, Fe and Mn
7000 series: Al + 4 to 9 % Zn + 1 to 3% Mg + Si, Fe, Cu and occasionally Zr and Ag

General properties

Density	2,5e3	-	2,9e3	kg/m^3
Price	* 1,68	-	1,8	EUR/kg
Date first used	1916			

Mechanical properties

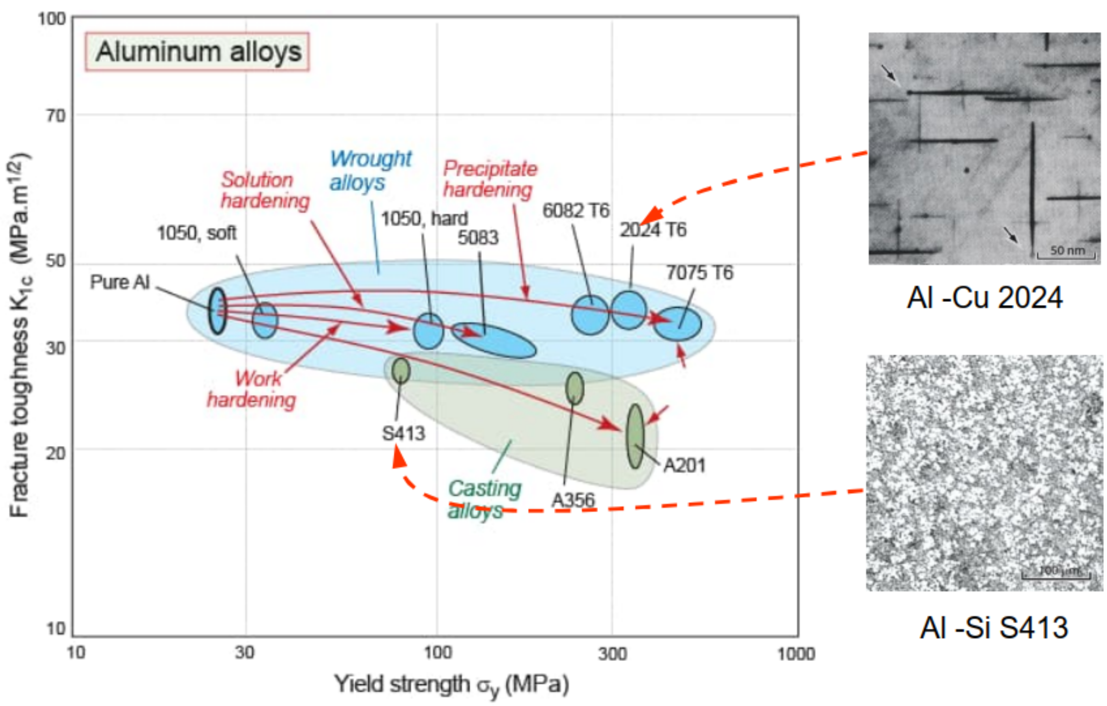
Young's modulus	68	-	80	GPa
Shear modulus	25	-	28	GPa
Bulk modulus	64	-	70	GPa
Poisson's ratio	0,32	-	0,36	
Yield strength (elastic limit)	95	-	610	MPa
Tensile strength	180	-	620	MPa

Aluminum
- Audi A8, Tesla, Jaguar XE, …
- light but expensive, difficult to repair
- 5xxx (strain hardening), 2xxx, 6xxx and 7xxx (precipitation hardening) alloys are
Used

Light alloys
- Aluminum
- Magnesium

- Titanium
- (Beryllium)

Aluminum alloys: strengthening and primary shaping



Owing to its impressive strength-to-weight ratio and other superior characteristics, aluminum has emerged as the favored metal for the aerospace industry. The multiple advantages of aluminum include [1]:

1. Exceptional malleability, facilitating the effortless creation of intricate aerospace parts.
2. Robustness even in conditions of intense stress, as well as extreme pressures and temperatures.
3. Economic viability relative to other metals, attributed to its lightweight nature.
4. Higher electrical conductivity

Out of the many series, the 2xxx and 7xxx aluminum alloys are common in high-strength aircraft structures. Particularly, the aluminum alloy 2024 is used extensively for aerospace and aircraft components [1]. It possesses high tensile strength, is treatable, and stress resistant for various applications such as aircraft wings. On the other hand, the aluminum alloy 7075 is used to strengthen aluminum aircraft structures, which has the best machinability and results in a neat finish [2].

How aluminum 2024 is heat treated: 2024 undergoes age-hardening by annealing at 398°-426°C for at least 2 hours, followed by slow cooling in the furnace. The T4 condition is attained by a 494°C heating and cold water quenching. Aging then occurs at room temperature. [3]

How aluminum 7075 is heat treated: 7075 is processed in T6 treatment. The first process is heat treatment in 480ºC for 2 hours, followed by rapid quenching. After this process, the aluminum alloy has process in ageing step 121°C for 24 hours. [4]

[1] https://www.howardprecision.com/what-is-aerospace-aluminum-aluminum-alloys-used-in-the-aerospace-industry/#:~:text=Alloy%202024%20–%202024%20Aluminum%20alloy,%2C%20aircraft%20wings%2C%20and%20repairs.

[2] https://www.experimentalaircraft.info/articles/aircraft-aluminum.php

[3] https://www.speedymetals.com/information/Material53.html#:~:text=2024%20is%20an%20age-hardening,10%20hours%20and%20air%20cooling.

[4] https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjs9rDluqKBAxUFJRAIHbyxDJ8QFnoECA0QAw&url=https%3A%2F%2Fpubs.aip.org%2Faip%2Facp%2Farticle-pdf%2Fdoi%2F10.1063%2F1.5024116%2F14153519%2F030057_1_online.pdf&usg=AOvVaw1LngTzMeuMr_7R5GT2d1OO&opi=89978449

Quiz 3

Question 1

Flag question   Marked out of 1.00   Not yet answered

Why is material modeling used widely nowadays?

Definition: A material model, or constitutive model, is a mathematical representation of the expected behavior of a given material in response to a physical phenomenon [1] (applied force, temperature, material phase evolution etc). Examples are Linear Elastic model (Hooke's law), the Plastic model (von Mises criterion, crystal plasticity, enHill48), damage models, cleavage/ductile fracture models (eMBW), composite and laminate material models, etc

Why is material modeling (MM) used widely nowadays?
1. Predictive Capabilities: MM allows engineers to predict the behavior of materials under various operating conditions without the need for extensive experimental testing. This can save time and resources. For example, crystal plasticity model can predict stress strain curve without conducting tensile testing
2. Design Optimization: Engineers can use MM to optimize designs for specific applications. For instance, aeronautics and aerospace requires higher performance and efficiency while ensuring maximum reliability and controlling costs. MM plays a central role in achieving those objectives [2]
3. Understanding Complex Phenomena: Some material behaviors, especially at the atomic or molecular level, are difficult to observe directly. Modeling provides insights into these behaviors, helping researchers understand mechanisms like hydrogen diffusion and phase transformations.
4. Integration into Computational methods: these MMs are highly optimized on various softwares, which enables large scale simulations and efficient automation workflow.

References:
[1] https://www.sciencedirect.com/topics/engineering/material-model
[2] https://www.hindawi.com/journals/ijae/2018/6296145/

Question 2

Flag question Marked out of 1.00 Not yet answered

What is the typical material modeling software?

Many MM softwares belong to the class of CEA (Computer-aided engineering) to deal with tasks related to engineering analysis. Most commercial CAE softwares support FEA (Finite Element Analysis) feature, which can derive material properties under different deformation schemes. The typical softwares falling into this type include Abaqus, Ansys, Siemens NX and CreoPTC. MATLAB, while a proprietary programming language, also supports a wide variety of MM simulation. There are many other softwares developed independently by many researchers and became open source. Some of them are:

1. MSC Marc: A nonlinear finite element analysis software used to simulate complex material behaviors and interactions.

2. MOOSE (Multiphysics Object-Oriented Simulation Environment): An open-source computational framework that provides a high-level interface for solving fully coupled systems of nonlinear partial differential equations.

3. DREAM3D (Digital Representation Environment for the Analysis of Microstructure in 3D): A software tool for reconstructing, processing, and analyzing 3D microstructure data, particularly useful for materials science applications.

4. DAMASK (Düsseldorf Advanced Material Simulation Kit): A simulation toolkit for multiscale modeling of crystalline materials, focusing on the mechanical behavior of metallic materials.

Question 3

Flag question Marked out of 1.00 Not yet answered

Any ideas to use machine learning models to boost the material modeling and material design?

Machine learning (ML) techniques enable us to infer relationships from a large amount of input data. Physical sciences have been quite behind to utilize the power of ML, even though their computational implementation is suited to modern simulation techniques already [1]. As a result, right now MM can greatly benefit from a number of ML applications, such as materials discovery and MM design that promise to accelerate development of novel technologies.

Some of the key points in applied ML for MM and material design are:
1. Neural networks: Obtain nonlinear correlation between material properties and material behavior. Neural networks are proven to model any types of functions (no matter how complex it is).
2. Graph neural networks: material and pattern discovery
3. K-clustering: can be used to categorize materials based on their properties or behaviors
4. Dimensionality reduction techniques: find which properties are the most likely cause of the observed behavior.
5. Compressed sensing can be used to reconstruct microstructural images or patterns from limited data, especially in techniques like electron microscopy or tomography.
5. Derivative-free optimization algorithm to find the optimum to a material design problem, such as Genetic algorithms and Particle Swarm optimization. They are usually coupled with a surrogate model like neural networks or polynomial functions.
6. Bayesian optimization: Nonparametric optimization algorithm with the same purpose above, but with the surrogate model as the Gaussian Process.

Reference:
[1]
https://courses.aalto.fi/s/course/a053X000012QxjwQAC/machine-learning-for-materials-science-d?language=en_US

Quiz 4

Question 1

Flag question | Marked out of 1 | Not yet answered

Considering the weldability concept which are the main features characterizing a welding application?

Weldability refers to the ability of a material to be welded under specific conditions without producing defects. When considering the weldability concept for a welding application, several key features characterize the process:

1. Type of Joints: it directly influences the strength, appearance, and functionality of the welded structure. The joint type must be chosen based on the intended application and loading conditions of the structure.
2. Type of edge shape for each component: The edge preparation or shape (e.g.,butt, tee, corner, lap, edge joint) affects the penetration of the weld [1], the amount of filler material required, and the quality of the weld. Proper edge preparation ensures better fusion, reduces the likelihood of defects, and enhances the mechanical properties of the weld.
3. Tolerances: it specifies the permissible limits of variation in the dimensions of the welded components. Tighter tolerances can lead to more consistent and higher-quality welds but may also increase the cost and complexity of fabrication.
4. The design criteria for joints depend on several factors: Welding Process, materials being welded, thickness of Components and joint accessibility

References:
[1] https://www.uti.edu/blog/welding/joint-types

Question 2

Flag question | Marked out of 1 | Not yet answered

Give 5 samples of welding processes and for each one identify its nature in terms of fusion welding

Fusion welding or simply metal welding, is a classification under homogeneous welding, that groups many processes that are defined as the method to heat two metals in higher temperatures until they melt, join or fuse each other [1]

The five types of welding processes with its basic form as fusion welding are [2]

1. Arc Welding
- Most popular type of fusion welding
- Relying on an electric arc to join two or more objects up to 6,000 degrees Fahrenheit
- highly capable of melting even the toughest metals.
- Can be performed underwater, which is ideal for offshore welding projects.

2. Laser Welding
- Involves the use of light radiation to produce heat.
- The laser welding rig blasts the surfaces with radiated light.
- With each blast, the surfaces become a little hotter and fuse together.

3. Induction Welding
- Distinguished from other types of fusion welding since there's no direct contact between an object's surface and the heat source.
- A wrapped coil is used to create a magnetic field that heats metal.
- The magnetic field quickly heats the metal, causing it to melt and fuse together.

4. Oxyfuel Welding
- Chemical-based fusion welding
- Using flame to heat and join surfaces, with oxygen as the fuel source.
- The oxygen fuels the fire to create a hot flame in excess of 4,500F

5. Solid Reactant Welding
- Relies on chemical reactions with certain materials to join them.
- There are compounds, for instance, that create heat when mixed together.

References:
[1]
https://texfire.net/en/blog/60_types-of-fusion-welding-oxyacetilene-electric-and-laser.html#:~:text=Fusion%20welding%20or%20simply%20metal,a%20metal%20contribution%2C%20by%20general
[2] https://monroeengineering.com/blog/the-5-types-of-fusion-welding/

Question 3

Flag question | Marked out of 1 | Not yet answered

Give example of 3 techniques used as non-destructive testing (NDT)? and identify the main the physical operational fundaments for each one.

Definition: NDT is used to inspect and evaluate materials, components, or assemblies without destroying their serviceability [1]. There are many NDT techniques,but they are broadly categorized into 3 major physical principles: Electromagnetic radiation, Electromagnetism, and Ultrasonic techniques.

1. Electromagnetic radiation: Its techniques include X ray, Gamma ray, Microwaves, Thermography, Infrared flash thermography, and Holographic interferometry. It is a method of characterizing the thickness or internal structure of a test piece through the use of high frequency sound waves [2]. High frequency sound waves are directional, and they will travel through a medium (like a piece of steel or plastic) until they encounter a boundary with another medium (like air), at which point they reflect back. By analyzing these reflections it is possible to measure the thickness of a test piece, or find evidence of cracks or other hidden internal flaws.

2. Electromagnetism: Its techniques include Magnetic particles, Eddy currents and Eddy currents arrays. It is the process of inducing electric currents and magnetic fields inside a test object and observing the electromagnetic response. A defect inside a test object creates a measurable response that differs from background noise and allows us to detect and characterize surface and sub-surface flaws in conductive materials. [3]

3. Ultrasonic: Its techniques include Ultrasonic conventional, Laser ultrasonic, Termosonics, ToFD, Phased arrays, EMAT and Guided waves. It is used to locate internal and external product defects and measure wall thickness discontinuities in metal tubing, pipe, and other materials without damaging the item being inspected. Ultrasonic testing detects flaws deep within the items being inspected by transmitting short, high-frequency sound pulse waves into the inspection item. [4]

References:
[1] https://www.asnt.org/MajorSiteSections/About/Discover_Nondestructive_Testing.aspx#:~:text=What%20Is%20Nondestructive%20Testing%3F,assemblies%20without%20destroying%20their%20serviceability.
[2] https://www.wermac.org/others/ndt_ut.html

[3]
https://www.nasa.gov/centers/wstf/supporting_capabilities/nondestructive_evaluation/electromagnetic_testing.html
[4]
https://www.nasa.gov/centers/wstf/supporting_capabilities/nondestructive_evaluation/ultrasonic_testing.html

Quiz 5

Question 1

Flag question Marked out of 1 Not yet answered

Name one reason to study failure

Engineering failure is often a rare, localized phenomenon, which is extremely hard to predict in the long run. One reason to study failure is to understand the root causes and mechanisms that led to the failure, allowing for the prevention of similar incidents in the future, thereby ensuring safety and reliability of the materials, components, and systems in operation.

Question 2

Flag question Marked out of 1 Not yet answered

Describe how similar failures can happen in different industries.

Similar failures can occur across different industries due to their shared underlying causes or mechanisms. Failures in materials and components often arise from fundamental causes such as material defects, manufacturing errors, operational conditions, or environmental factors. Since many industries utilize similar materials, technologies, and processes, they can be susceptible to the same types of failures. The most notable common forms of failures across many industries are fatigue, creep, brittle fracture, ductile fracture, plastic deformation and environmentally assisted failure such as corrosion.

For example, fatigue is the common failure reason in the aerospace industry [1] and railway industry [2], while corrosion is the common failure reason in gas industry [3] and maritime industry [4].

References:
[1] https://www.researchgate.net/publication/37181698_Fatigue_failure_of_aircraft_components
[2] https://www.researchgate.net/publication/245390338_Railway_axle_failure_investigations_and_fatigue_crack_growth_monitoring_of_an_axle
[3] https://www.dfctank.com/news/corrosion-of-oil-pipelines-and-storage-tanks.html
[4] https://www.corrizonsg.com/marine.html

Question 3

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Is there a problem with Nickel alloy 690 under stress?

Nickel alloy 690 is a high-chromium nickel alloy that exhibits excellent resistance to many corrosive aqueous media and high temperature environments. It has good fabrication characteristics, metallurgical stability and high strength [1]. However, when under stress in operating conditions such as as a heat exchanger tube in a steam generator (SG), the Nickel alloy 690 have experienced a variety of corrosion problems such as pitting, intergranular attacks (IGA) and stress corrosion cracking (SCC) [2]. In spite of considerable efforts to reduce the material degradation, SCC remains an important problem to be overcome. These are the common problems that Nickel alloy faces during operation, especially stress corrosion cracking is the most serious potential failure type

References:
[1] https://www.azom.com/article.aspx?ArticleID=9964#:~:text=It%20has%20good%20fabrication%20characteristics,under%20various%20high-temperature%20solutions.
[2] https://www.sciencedirect.com/science/article/pii/S1738573315300085

Quiz 6

Question 1

Flag question Marked out of 1.00 Not yet answered

What is a core in sand casting?

The core shapes the hollow features of the component. The primary purpose of a core therefore is to create internal features in a casting that cannot be formed by the pattern alone. The internal features may include cavities and holes. Cores are made of a sand mixture but they often contain a stronger binder to ensure they retain their shape when molten metal is poured into the mold. After the metal has solidified and the casting is removed from the mold, the core is broken up and removed from the casting

Question 2

Flag question Marked out of 1.00 Not yet answered

From the naming, explain with details of 'EN-GJS-500-7'

EN-GJS-500-7C, also known as GGG50, is a material with a predominantly ferritic/pearlitic structure and is one of the most commonly used in the ductile iron family. This grade offers good tensile strength and a satisfactorily high yield point combined with good toughness, which makes this the grade of choice across many industries [1]

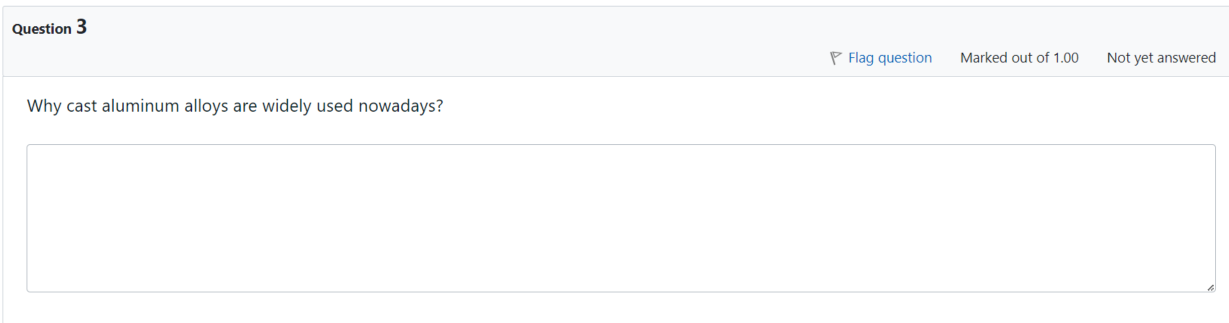
EN: This stands for "EuroNorm," indicating that the material specification follows a European standard.

GJS: This stands for "spheroidal graphite iron". Resistance and ductility are two of the most important characteristics of ductile iron (GJS). Thanks also to the spheroidal shaped graphite nodules, spheroidal graphite iron (GJS) not only boasts superior mechanical properties with respect to grey cast iron, but is also higher performing and more ductile. Unlike the flake-like structure of grey cast iron, the spheroids of ductile iron GJS inhibit the spread of cracks, thus making it possible to obtain parts that are more resistant and high-performing over time. [2]

500: This number represents the minimum tensile strength of the material in megapascals (MPa), which means the ductile iron has a minimum tensile strength of 500 MPa.

7: This number represents the minimum elongation percentage. The material has a minimum elongation of 7% when subjected to a tensile test.

References
[1] https://www.tasso-bar.com/en-gjs-500-7c/
[2]
https://zanardifonderie.com/en/spheroidal-graphite-iron-gjs/#:~:text=Thanks%20also%20to%20the%20spheroidal,higher%20performing%20and%20more%20ductile.



Aluminum alloys are widely used nowadays due to these properties:
- Suitable for complex thin-walled parts
- High dimensional accuracy and low weight with high rigidity
- Good strength-weight ratio
- Smooth surfaces and edges and good machinability
- High thermal conductivity and high electrical conductivity
- Corrosion and weathering resistance
- Several surface treatments possible