MONASH University
Engineering

ENG1001
Team assignment cover sheet

Assignment details			
Title of assignment	Materials Assignment	**Team #**	105
Lecturer/tutor	Mr Ian Daryl Sta Maria	**Tutorial day and time**	Wednesday, 9 am MYT
Due date	24/12/2020	**Date submitted**	24/12/2020

Submission date and extensions			
Lecturer/tutor			
Extension granted until		**Signature**	

Declaration

- I understand that this assignment is to be completed as a team, with all members working together and sharing the workload. Individual marks will be scaled according to the percentage contributions of each team member, with increases in marks capped at 110%.
- I realise that we may be asked to identify those portions of the work contributed by each of us and required to demonstrate our individual knowledge of the report by answering oral questions or by undertaking supplementary work, in order to arrive at the final assessment mark.
- I have read the university's statement on cheating and plagiarism, as described in the Student Resource Guide
- This assignment is original and has not previously been submitted as part of another unit/subject/course
- I have taken proper care of safeguarding this work and made all reasonable effort to ensure it could not be copied
- I acknowledge that the assessor of this assignment may for the purposes of assessment, reproduce the assignment and provide it to another member of faculty
- I understand the consequences for engaging in plagiarism as described in Statute 4.1. Part III – Academic Misconduct
- I certify that I have not plagiarised the work of others or participated in unauthorised collusion when preparing this assignment.

The intention is for all members to contribute evenly. If you agree that all team members have contributed a fair share, please tick the box below and do not fill in individual contributions. If there is a large difference in the amount of work that each person completed, please discuss among your group and allocate percentages out of 100% for each person in the box below. For teams of 3, percentage contributions should add to 300%, and for teams of 4, 400%. Your individual assignment mark will be the team's mark multiplied by your percentage contribution, however increases in marks will be capped at 110%.

Student details

☐ Tick if all team members contributed equally, *or* fill in percentage contributions below

Student ID	Name	% contribution	Signature
32194471	Tan Jin Chun	100 **/100%**	
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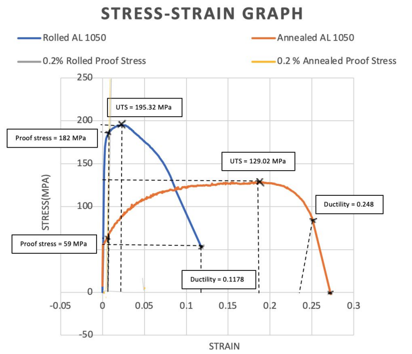
32190247	Pratik Bontha Venkata Surya	0 **/100%**	

Please note that it is your responsibility to retain a copy of your assignment

Part 1 Question 1

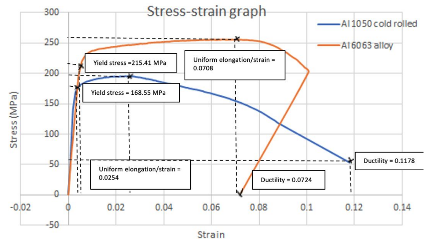


Samples	UTS(MPa)	Toughness(J/m^)	Ductility%	0.2%Proof Stress(MPa)
Cold-Rolled	195.32	19.45	11.70	182
Annealed	129.02	33.46	24.80	59

a) The uncertainty for Proof Stress and Ultimate Tensile Stress is 0.58% and the uncertainty for ductility and Toughness is 0.04%.

b)Annealing will cause changes to the metal's nano scaled structure which changes its mechanical properties.The dislocation density of the material will reduce.The atoms will have sufficient energy to move in response to internal stresses.When the metal is heated to a higher temperature, a larger proportion of the dislocations will be removed and each grain's crystal structure will be randomly aligned. The proof stress and the ultimate tensile stress will be reduced. When the dislocation density is reduced, the total number of dislocations dramatically decreases. The distance between the dislocation increases. The majority of the interactions are repulsive. There will be a larger movement compared to the usual cold working dislocation arrangement. The decrease in the restriction of the dislocation will lead to a decrease in strength. This will increase the ductility of the metal and reduce the toughness of the metal.

Part 1 Question 2



a) The uncertainty for yield stress is 0.58% whereas for ductility and uniform elongation is 0.04%.

Sample	Yield stress(MPa)	Ductility(%)	Uniform Elongation/Uniform Strain
Al 1050 Cold rolled	168.55	11.78	0.0254
Al 6063 Alloy	215.41	7.24	0.0708

b) Precipitate hardening occurs when two different metallic elements are melted. The minor elements form a supersaturated solution due to its concentration as it cools. Along with mild heating the minor elements (the one that forms the precipitate) diffuses through the structure and reacts to form a nanoscale particle. These nanoscale particles that are spread throughout the material are called precipitates. The precipitates disorganises the crystal structure impeding the movement of the dislocations until larger stresses are applied.

c) The uniform elongation (the maximum deformation that can occur before a neck starts to form) is an advantage for the alloy sample as opposed to the cold rolled sample because it is much stronger and has a higher ultimate tensile stress value.

Part 1 Question 3

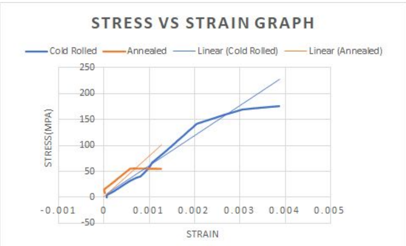
a)

b)Similarities: Young's Modulus for both samples should be the same as they are made of the same material

Differences: The graph for Stress vs Strain for Measured Annealed sample starts from the origin, while the graph for Stress vs Strain for Fully Annealed sample starts from (0.00057143, 40), as it is simply a rough sketch and we cannot determine if it starts from the origin or not.

Number of dislocations: The measured annealed sample has a higher yield strength and UTS which implies that it has a greater number of dislocations than the fully annealed sample as they prevent each other from moving (dislocations allow slip to proceed at stresses lower than the predicted yield stress if they move towards the end of the crystal/lattice). The process of annealing involves reducing the dislocation density of the sample, which decreases strength and increases ductility.

Part 1 Question 4

a) 

The modulus obtained from the best fit line of the graph for AL1050 Cold Rolled Sample will be approximately = 53152MPa

The modulus obtained from the best fit line of the graph for AL1050 Annealed Sample will be approximately = 94879MPa

b)The work hardened sample and the annealed sample both have the same modulus but have different dislocation densities.The dislocations produced by work hardening will not affect the elastic properties such as the Young's modulus since the dislocations consist of a relatively small volume fraction of the overall volume of the metal. Besides that, the dislocations hinder the movement of a new dislocation. When stress increases just beyond the yield strength of a non-work hardened sample, a work hardened sample will continue elastic deformation. Thus, the Young's Modulus remains unchanged.

c)By analysing the graph, the Young's Modulus of each material can be obtained.For cold rolled samples, the strain and the yield stress at the elastic point is 0.004979 and 180.65 respectively.The Young's Modulus is approximately 36282.4 MPa.

The inverse of this value indicates the strain per unit stress value which is 2.76*10^-5.

For the annealed sample , the strain and the yield stress at the elastic point is 0.001267 and 55.707 respectively. The Young's Modulus will be approximately 43967.6MPa.The inverse of the value will also indicate the strain per unit stress value which is 2.27*10^-5.Since the precision of the measuring instrument is smaller than 20 micrometer than the incremental slope of the graph within the elastic limit. So, the device is precisely suitable for the measurement of both the specimens.

Part 2 Question 1

Question 1 (a)

The minimum cross-sectional area required is obtained by using the formula

P <= бy*A

Where P is the squash load in Newton , бy is the stress of the material in MPa and A is the cross-sectional area.

100*10^3 <= 40*A

A => 2500mm^2

Question 1 (b)

The minimum second moment of area is obtained by using the Euler's Buckling formula which is given as P = (π^2*E*I)/(k*L)

Where P is the Euler's buckling load , π is a numerical constant which has a value of 3.142 , E is the Young's Modulus in MPa , I is the second moment of area in mm^4 , k is the effective length factor which is dependent on the joints at each end of the member which is assumed to be pin-jointed. The value of k will be 1 and L is the members length

Firstly, E is converted from GPa to MPa

70*10^3

= 70000MPa

The Euler's buckling formula is used

100*10^3 = ((3.142^2)*70000*I)/(1*1100^2)

I = 0.175mm^6 is obtained

Question 1 (c)

Based on the dimensions and properties

Square Hollow Section(SHS): Grade C350

Since the thickness cannot be less than 5mm

The following designation is chosen based on the required thickness, Second moment of area and cross-section area

100X100X9.0mm

Question 1 (d)

Total number of members = 23

Convert 2500mm to m by dividing 2500mm with 1000000

Volume of a member = (1.1*2.5*10^-3)

= 2.75*10^-3 m^3

Mass of the members = final volume of the members*density of AL1050

2.75*10^-3 * 2700 = 170.775kg

Question 1 (e)

The cost per kg is given as 2.25$

2.25*170.775 = 384.24$

The carbon footprint per kg is 11

11*170.775 = 1878.53kg

Material	Final Dimensions	Cross-Sectional Area(mm^2)	Second Moment of Area(10^6 mm^4)	Volume m^-3	Mass kg	Cost $
Treated Pine(knot-free)	88x88x5	2564	1.226	2.82	1.55	2.015
CFRP(Carbon fibre reinforced polymer)	50x50x5	156	0.1115	0.1716	0.2488	9.9528
Wrought Magnesium Alloy	100x100x5	385	0.2452	0.385	0.616	2.156
Aluminium 2024 T6	100x100x5	286	0.1657	0.286	0.7722	2.085
Polycarbonate	125x125x5	1282	4.09	1.41	1.692	8.29
Concrete	250x250x6	5000	0.613	5.5	13.2	1.58
Low Carbon Steel (AISI 2020)	50x50x5	250	0.0613	0.275	2.16	1.62
Titanium Alloy	50x50x5	91	91	0.100	0.45	11.25

Part 2 Question 2

Example Calculations and Explanations for Treated Pine (knot-free)

100*10^3 <= 39*A
A => 2564 mm^2
10*10^3
= 10000MPa
100*10^3 = ((3.142^2)*10000*I)/(1*1100^2)
I = 1.226 mm^6
Volume of a member = (1.1*2.564*10^-3)

2.82*10^-3 m^3

Mass of a member = (2.82*10^-3*550)

= 1.551 kg

The cost per kg is given as 1.30$
1.30*1.551 = 2.0163$
The carbon footprint per kg is 0.38
0.38*1.551 = 0.589kg

Part 2 Question 2

Treated pine is a type of pine that has been treated which makes the timber a more viable option for building, construction, and engineering application. Pine wood is cheap, strong and as good, per unit weight, as any man-made object except for CFRP. However, pine wood can be easily damaged and is susceptible to scratches and dents. Generally, pine wood is not suitable for SHS. The amount of energy needed to make a hollow section would be time consuming and impractical as pine wood is generally used In it's whole and cutting down trees is not eco-friendly. CFRP (Carbon fibre reinforced polymer) is an extremely durable, strong and light material. The volume of CFRP is the lowest compared with the other materials in Table 2 and suitable to use an SHS design requirement . However, the cost for CFRP is generally on the high end. It is used in the manufacturing of the wing's aircraft and golf clubs.Wrought magnesium alloy has a low density, good mechanical damping and has moderate thermal and electrical conductivity compared to other metals. Wrought magnesium alloys have a special characteristic. The compressive proof strength is smaller than tensile proof strength. Wrought magnesium alloys come in the form of a hollow tube or square section. However, the extraction of magnesium is very energy intensive, consuming nearly two times more per unit weight than aluminium.The carbon footprint of wrought magnesium alloy is the highest among the materials chosen. This is not in line with the goals of the local council. Aluminium 2024 T6 is a type of aluminium alloy and used in applications requiring high strength to weight ratio, as well as good fatigue resistance. However , Aluminium is usually softer than steel and it corrodes rapidly in sea water.Polycarbonate has a very low fatigue endurance and the properties of the material tend to be degraded with exposure to the UV-spectrum. However UV-resistance can be implemented on the polycarbonate by developing a coating increasing its cost. It would be a wiser choice to use this material for the roofing as opposed to the actual truss itself as it is not scratch or denting resistant. Although concrete has a large durability, it has a large weight compared to its strength and is extremely brittle. A fully square or circle cross-sectional area would be a better option for this material making it more stronger although it clashes with the SHS and minimum mass requirement. Low carbon steel on the other hand, has a very good strength to cost ratio and has a low carbon footprint. Generally, steel based bridges can be manipulated to produce a very attractive design as steel can be bent and twisted easily. The only downside is its large density results in its overall self weight of the truss being very large. Titanium alloy has the highest strength and durability. However, it has a very large density and is also very expensive leading to it being cost – prohibitive as a construction of a truss bridge requires large quantities of materials. Titanium alloy also has the largest carbon footprint per kg on the ecosystem making it a very environmentally unfriendly material to be used in the construction of such a truss bridge over a long distance.Materials that have a higher yield stress require a smaller area/size of member due to its high strength. This results in the volume of the members being small resulting in the ease of producing a light and delicate looking bridge. The second moment of area which is the resistance of the component from bending about a certain axis decreases as the modulus of elasticity, E of the material increases. Furthermore, materials with a ductility value do not comply with the requirement of the beam being an SHS design it would be wiser to use complete circle or square cross-section instead as they are quite similar.

Part 2 Question 3

Materials	CFRP(Carbon fibre reinforced polymer)	Concrete	Low carbon steel (AISI 1020)
Fatigue strength (MPa)	150-300	0.54-0.84	203-278
Fracture Toughness(MPa)	6.12-20	0.35-0.45	41.6-79
Poisson’s Ratio	0.305-0.307	0.13-0.16	0.28-0.29

Three other additional properties that are crucial to be considered before finalising on the material for the bridge are fatigue strength at 10^7 cycles, poisson’s ratio and fracture toughness. Fatigue strength is the highest stress that can be applied for a certain number of cycles without fracture. Since this property is greatly affected by environmental factors like corrosion it is vital that it is considered for the building of a truss bridge with long term performance. Poisson's ratio is the deformation (either contraction or expansion) of a material in the direction perpendicular to its loading. It is an important measurement of the Poisson effect whereby a material tends to contract at a transverse direction to which it is stretched and the converse is also true. Thus, before designing a bridge it is important that this factor is considered to completely understand the ripple effect of loading. Fracture toughness is an indication of the critical stress intensity factor of a sharp crack to propagate a pre-existing flaw. The material's thickness influences the constraint conditions at the beginning of the crack. Whereby thick components exert a plane strain whereas thin components exert plane stress conditions. This would be an important factor to consider in designing a delicate and aesthetic looking bridge as per the requirements.

Firstly, the fatigue strength ranking for the materials above is CFRP>Low carbon steel(AISI 1020)>Concrete. This could be explained using the general rule of thumb which is fatigue strength is approximately one third (⅓) of the materials tensile strength and CFRP has the highest tensile strength with concrete having the lowest tensile strength. Secondly, the fracture toughness ranking for the materials above is Low carbon steel (AISI1020) > CFRP > Concrete. This is because metals generally have a high resistance to cracking and alloys exceed the individual elements fracture toughness.Concrete has the lowest fracture toughness because it is a composite ceramic and ceramics have the least fracture toughness. Thirdly, the Poisson's ratio ranking for the materials above is CFRP > Low carbon steel > concrete. For most materials this property is in the range of 0-0.5. This is because CFRP is quasi- isotropic (having isotropic properties in only one plane) whereas concrete and low-carbon steel is mostly isotropic with identical material properties in all directions. However, concrete is the most isotropic among the three causing it to have the lowest poisson's ratio.

Part 2 Question 4

The best 2 options for the final beam design are CFRP(Carbon fibre reinforced polymer) and Low carbon steel(AISI 1020).CFRP is generally a very durable material and has a very high strength to weight ratio. It has also one of the strongest reinforcing fibres as it is very hard to stretch and bend.It is also one of the most corrosion-resistant materials and the fibres will not wear out quickly under the stress of constant use. However , there are downsides to CFRP. The first bane would be the cost of CFRP . The price of CFRP is very high as the demand for CFRP is very high. The next bane would be the ductility of CFRP. The ductility of CFRP is low as the carbon fibre will break and shatter when it's compressed beyond its strength capabilities or exposed to high impact.The low carbon steel is the most common ,cost effective ,malleable and ductile metal there is. However , Low-carbon steels suffer from yield-point runout and it is also more susceptible to rust and corrosion when compared to other steels.