



BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	Rhys Brannan	Student P number:	2220480
Programme:	<u>Full time manufacturing programs</u>		
Module:	Materials and introduction to processing	Module Level (4, 5, 6):	4
Module code:	ACMA4000	Contribution to Overall Module Assessment (%):	50
Lecturer:	Chris Wyatt	Internal Verifier:	Kelvin Lake
Assignment Title:	Rubber properties	Assignment No (x of x):	1
10	12/10/22	Submission deadline:	14/11/2022

Referencing:	In the main body of your submission you must give credit to authors on whose research your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have read or quoted in order to complete this assignment (e.g. for books: surname of author and initials, year of publication, <u>title of book</u> , edition, publisher: place of publication).			
Disclosure:	I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people. All references have been duly cited.			
Student's Signature:	Assignments will not be accepted without a signature here 	Date:	14 / 11 / 22	
Turnitin: Lecturer to tick to indicate if an electronic version of the assignment must be submitted to Turnitin. Note: the Turnitin version is the primary submission and acts as a receipt for the student. Both electronic and paper versions MUST be submitted by the same deadline. No marks will be released until both submissions are received. Late submission of the electronic version will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, Refer.			YES	☒
			NO	☐

Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
an understanding of the structure and properties of metals and polymers	- Design simple experiments in material science - Understand key material properties such as UTS, young's modulus, fatigue limit, toughness - Understand the underlying science, stress, strain, energy - A basic understanding of how chemistry and structure affects material properties - An understanding of elastomers – their behaviour and chemistry

- Please submit the assignment parts via moodle

- This form (ALL PAGES) MUST be at the front of the paper submission. Assignments will not be accepted without this form as it is a requirement that you sign the disclosure regarding referencing convention.
- DO NOT put this form into Turnitin or it will match many similarities with other students' submissions.

TASK DESCRIPTION

(Lecturer – please insert task(s) / questions / what the student must do, here)

You are tasked with finding the stress strain curve for a rubber material used to create a rubber band of your choice. Ideally you should also look at rubber phenomena such as creep, hysteresis and fatigue fractures.

For this task you will not be given a “packaged” practical session – rather you will have to design the experiment(s) yourself using materials you have at hand – or can purchase cheaply. Part of the assignment is to critically evaluate your own experiment but you will not gain marks by spending lots of money!

Research Required:

Using the internet and the library research and understand the following.

Rubber

- 1) Key Properties of Rubber materials
- 2) Underlying chemistry which creates these properties
- 3) Stress strain curves
- 4) Young's Modulus
- 5) Ultimate tensile stress
- 8) Creep in materials
- 7) Mechanical energy absorption in materials.
- 8) Hysteresis
- 9) Material property variation.
- 10) Visco elastic behaviour
- 10) Historical development of nature rubber and synthetics.

You do not need to write up or summarise research – rather it should be evident that you understand these things based on how you design, conduct, introduce and report your experiment (s)

Design of experiments

Ingredients:

A method to measure the cross sectional area of a rubber band.

A method to stretch a rubber band using a known force

A method to measure the length of the unstretched and stretched band

Minimum Work Required.

- 1) Obtain a Force/Stretch data for a rubber band of your choice. Take the curve to the point the band snaps
- 2) Convert the data into an engineering stress/engineering strain curve for the material.
- 3) Convert the curve into a true stress / true strain curve for the material
- 4) Find young's modulus at the initial stretch point and the ultimate tensile strength of the material based on the true stress and true strain curve
- 5) Observe how the chemistry of rubber materials dictates how the curve works
- 6) Analyse your experimental accuracy. What are the sources of variation in the result? How could the sample (the band) be better prepared? If you had more money and time how could you make the experiment more accurate and more repeatable?
- 7) Analyse the cost of the experiment in terms of time and money. Reflect on the trade-off between quality and cost

Additional marks can also be given for additional work :

- 1) Analyse the variations in result for a sample of supposedly identical bands. ie repeat the test number of times . Get the mean and standard deviation of the result
- 2) Conduct fatigue testing on a sample of bands – this requires you to stretch the band with a known force repeatedly until it breaks – counting the number of cycles until the break occurs. The known force should start at $0.3 \times$ breaking force – then repeat the whole experiment at $0.4 \times$ breaking force etc
- 3) Try to understand the effect of temperature on the properties. If you have a walk-in fridge or a sauna – you could use that. Alternatively, you could repeat the test at different times in the day to get varying temperature. It is important that the temperature is held constant throughout the experiment and the measurement reflects the temperature of the band. Hair dryers do not work.

The most important instruction : Have fun and learn something! 😊 . And more seriously think about safety and damage – especially if you are using liquids! Bands will snap!

Write up :

You are required to write a report in English (Max 2500 words) .

It is suggested that you use the following titles.

Introduction : State the problem to be solved. Discuss the theory of elastomer behaviour (with references) and how it relates to your experiment(s)

Experimental method : Describe your method (with pictures as well as words).

Results: Clearly lay out your experimental results. Use tables where necessary. Make sure units are clear to the reader throughout

Analysis of results : If you use a spreadsheet make sure you write up all the equations properly (use the equation editor in word and make sure the reader understands exactly what any variable names refer to. Quote the units

Analysis of experimental inaccuracy and cost/quality trade-off. How could your experiment be improved? How can you reduce variation caused by the experiment rather than the natural variation on the sample.

Discussion: How do your results reflect the established theory? What would you like to do if you had more time/money.

Conclusion: Don't bring in anything new – just summarise the results, analysis and discussion

Acknowledgements: Did you work with each other – Say so and how and acknowledge it. Did your mum allow you to use the kitchen? Say so!

References. Formal reference section – don't forget to put the references in your main text as well [1] !

References :

[1] UWTSD , UWTSD Referencing handbook , https://uwtsd.ac.uk/media/uwtsd-website/content-assets/documents/library-and-learning-resources/infoskills/IEEE-eng_v.1.2.pdf

Supplementary Rules:

Please feel free to work in groups to share research findings and exchange ideas. YOU MUST ACKNOWLEDGE OTHER STUDENTS WHO YOU HAVE WORKED WITH!

GUIDANCE FOR STUDENTS IN THE COMPLETION OF TASKS

Follow the class video carefully to understand some of the analysis techniques

MARKING CRITERIA AND STUDENT FEEDBACK

This section details the assessment criteria. The *extent* to which these are demonstrated by you determines your mark. The marks available for each criterion are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Common Assessment Criteria Applied	Marks available	Marks awarded
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions.		
Ability to find credible information Research items	10	
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		
Demonstrate that you understand Rubber possibly relevant research topics 1) Key Properties of Rubber materials 2) Underlying chemistry 3) Stress strain curves 4) Young's Modulus 5) Ultimate tensile stress 8) Creep in materials 7) Mechanical energy absorption in materials. 8) Hysteresis 9) Material property variation. 10) Poisson's ratio And that you have started to become aware of the issues around Design of experiments. Do not include material in your report if you do not think it is relevant.	15	
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence		
Demonstrate that you can convert force/stretch data to Stress/strain data Demonstrate you are beginning to understand the issues around sampling. Be able to compute a mean and standard deviation from a sample Show that you have begun to be able to analyse repeatability in experiments. Show that you understand engineering units in a practical environment	25	
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems.		
Show creativity in your solution to measurement and experimental procedure	35	
5. Skills for Professional Practice Attributes in professional practice: individual and collaborative working; deployment of appropriate media; presentation and organisation.		

Presentation	15	
Referencing, Structure, diagrams and pictures		

Assignment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		%
	Up to one-week late	40	
	Over one week late	0	

COMMON ASSESSMENT AND MARKING CRITERIA

Assessment Criteria	OUTRIGHT FAIL	UNSATISFACTORY	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT	EXCEPTIONAL
	0-29%	30-39%*	40-49%	50-59%	60-69%	70-79%	80-100%
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions	Little or no evidence of reading. Views and findings unsupported and non-authoritative. Referencing conventions largely ignored.	Poor evidence of reading and/or of reliance on inappropriate sources, and/or indiscriminate use of sources. Referencing conventions used inconsistently.	References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently.	Inclusion of a range of research-informed literature, including sources retrieved independently. Referencing conventions mostly consistently applied.	Inclusion of a wide range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied.	A comprehensive range of research informed literature embedded in the work. Excellent selection of relevant and credible sources. High-level referencing skills, consistently applied.	Outstanding knowledge of research-informed literature embedded in the work. Outstanding selection of relevant and credible sources. High-level referencing skills consistently and professionally applied.
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.	Major gaps in knowledge and understanding of material at this level. Substantial inaccuracies.	Gaps in knowledge, with only superficial understanding. Some significant inaccuracies.	Evidence of basic knowledge and understanding of the relevant concepts and underlying principles.	Knowledge is accurate with a good understanding of the field of study.	Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.	Excellent knowledge and understanding of the main concepts and key theories. Clear awareness of challenges to established views and the limitations of the knowledge base.	Highly detailed knowledge and understanding of the main theories/concepts, and a critical awareness of the ambiguities and limitations of knowledge.
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence	Unsubstantiated generalisations, made without use of any credible evidence. Lack of logic, leading to unsupportable/missing conclusions. Lack of any attempt to analyse, synthesise or evaluate.	Some evidence of analytical intellectual skills, but for the most part descriptive. Ideas/findings sometimes illogical and contradictory. Generalised statements made with scant evidence. Conclusions lack relevance.	Evidence of some logical, analytical thinking and some attempts to synthesise, albeit with some weaknesses. Some evidence to support findings/ views, but evidence not consistently interpreted. Some relevant conclusions and recommendations, where relevant	Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. An emerging awareness of different stances and ability to use evidence to support the argument. Valid conclusions and recommendations, where relevant	Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive arguments, and to review the reliability, validity & significance of evidence. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions / recommendations.	Thoroughly logical work, supported by evaluated evidence. High quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Strong, persuasive, conclusions, justifiable recommendations.	Exceptional work; judiciously selected and evaluated evidence. Very high quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Highly persuasive conclusions
4. Practical Application and Deployment Effective deployment of appropriate methods, materials, tools and techniques; extent of skill demonstrated in the application of concepts to a variety of processes and/or contexts; formulation of innovative and creative solutions to solve problems.	Limited or no use of methods, materials, tools and/or techniques. Little or no appreciation of the context of the application.	Rudimentary application of methods, materials, tools and/or techniques but without consideration and competence. Flawed appreciation of the context of the application.	An adequate awareness and mostly appropriate application of well established methods, materials, tools and/or techniques. Basic appreciation of the context of the application.	A good and appropriate application of standard methods, materials, tools and/or techniques. Good appreciation of the context of the application, with some use of examples, where relevant.	A very good application of a range of methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.	An advanced application of a range of methods, materials, tools and/or techniques. The context of the application is well considered, with extensive use of relevant examples. Application and deployment extend beyond established conventions. Innovation and creativity evident throughout.	Outstanding levels of application and deployment skills. Assimilation and development of cutting edge processes and techniques.
5. Skills for Professional Practice Demonstrates attributes expected in professional practice including: individual initiative and collaborative working; deployment of appropriate media	Communication media is inappropriate or misapplied. Little or no evidence of autonomy in the completion of tasks. Work is poorly structured and/or largely incoherent.	Media is poorly designed and/or not suitable for the audience. Poor independent or collaborative initiative. Work lacks structure, organisation, and/or coherence	Can communicate in a suitable format but with some room for improvement. Can work as part of a team, but with limited involvement in group activities. Work lacks coherence in places and could be better structured.	Can communicate effectively in a suitable format, but may have minor errors. Can work effectively as part of a team, with clear contribution to group activities. Mostly coherent work and is in a suitable structure.	Can communicate well, confidently and consistently in a suitable format. Can work very well as part of a team, with very good contribution to group activities. Work is coherent and fluent and is well structured and organised.	Can communicate professionally and, confidently in a suitable format. Can work professionally within a team, showing leadership skills as appropriate, managing conflict and meeting obligations.	Can communicate with an exceptionally high level of professionalism. Can work exceptionally well and professionally within a team, showing advanced leadership skills. Work is exceptionally coherent, very

to communicate (including written and oral); clarity and effectiveness in presentation and organisation.						Work is coherent, very fluent and is presented professionally.	fluent and is presented professionally.
--	--	--	--	--	--	--	---

Student Self Evaluation Form

Student name:		Student P number:	
Programme:		Year of programme	
Assignment Title:			

This section repeats in brief the common assessment criteria detailed on previous pages. The *extent* to which these are demonstrated by you determines your mark. Using these criteria, tick the box that best indicates the level of achievement you feel you have achieved with regard to each of them.

Common Assessment Criteria Applied	Level of Achievement						
	REFER		3 rd	2:2	2:1	1 st	1 st
	OUTRIGHT FAIL	UNSATISFACTORY	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT	EXCEPTIONAL
1. Research-informed Literature	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
2. Knowledge and Understanding of Subject	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
3. Analysis	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
4. Practical Application and Deployment N/A	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
5. Skills for Professional Practice N/A	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐

PLEASE COMMENT ON AREAS IN WHICH YOU FEEL THAT YOU HAVE PERFORMED WELL	PLEASE COMMENT ON AREAS YOU FEEL THAT YOU NEED TO DEVELOP

Student's Name		Date	
Student's Signature			



PRIFYSGOL CYMRU
Y Drindod Dewi Sant
UNIVERSITY OF WALES
Trinity Saint David

Finding the stress strain curve for a rubber material used to create a rubber band.

University of Wales Trinity
Saint David

School of engineering

Tenisle test to obtain
stress/strain curve of rubber

Rhys Brannan / 2220980

Mechanical Engineering

14/11/2022

Materials & intoroduction to
processing

Material & into to processing assignment

Introduction

I have been tasked with obtaining the stress strain curve for rubber, for this I will be looking at rubber materials such as rubber bands and putting them through a tensile test. This tensile test will be made at home using materials and apparatus that is available to me at a low cost.

Rubber is a polymer, which is a chain of repeating units called monomers. In rubber the repeating unit is isoprene, a carbon compound that has two carbon-carbon double bonds. Isoprene molecules will gather together, and one molecule attacks a carbon-carbon double bond of a neighbouring molecule. This will cause one of the bonds to break and the electrons reposition to form a bond between the two isoprene molecules. This procedure continues until you get long strands of many isoprene molecules connected in a chain. Due to the long chains, it is now called a polyisoprene polymer. Each polyisoprene chain contains numerous isoprene monomers. As the process resumes the polyisoprene chains stick together forming electrostatic bonds. These bonds hold the rubber fibres together and relates to its mechanical properties, for example elasticity. The molecular structure of rubber materials allows them to return to their standard shape after being compressed or stretched, this is apparent in rubber bands. When a rubber band is stretched or compressed it temporarily pulls or pushes the individual molecules out of alignment with one another. Once the stretching or compression force is removed then the molecules return to their original shape as they are attached to each other.

Thermal contraction also relates to the electrostatic bonds within rubber, whilst most engineering materials expand when heated rubber does the opposite and contracts. This is the result of how rubber molecule responds to heat. The molecules are twisted in rubber so when heat is applied it causes them to become more tangled and twisted resulting in the rubber reducing in size. But when the heat is removed, over time, the molecules return to their resting state and the rubber will return to its original shape. This is something I want to look at in my experiment, how the rubber band will stretch when a heat gun is added.

Experimental Method

Equipment:

- Rubber band
- Tape measure
- 400mm of 40x40 mild steel box section with hole drilled for hanging of rubber band
- Tap water
- Bucket x2
- Shoelace
- Weighing scale
- G-clamp
- M6 nut and bolt
- Water bottle
- Stopwatch

Study area

This test will be carried out at my workplace (Swansea University) at room temperature. The test will be conducted here as I know I will have the resources to hand and the correct amount of space.

1. Ensuring I have the correct equipment available, clamp the box section to the work bench using the G clamp provided. Once this is done, I place the M6 bolt through the hole and

thread the nut on the other side ensuring the bolt is secure, allowing enough room for the rubber band to be hung (6mm)



2. Once the rubber band has been hung measure the length whilst it is not under tension. I record my answer on a piece of paper.
3. Next, I weigh the plastic bucket whilst it is empty with the shoelace attached, again recording my answer on a piece of paper. Then attach the bucket to the rubber band via the shoelace so the rubber band is under tension, I measure the length on the rubber band using the tape measure and record my answer



4. Once the measurement has been recorded, I place the empty water bottle on the scale, once weighed I zero the scale so the weight of the bottle is not considered when filled with water.
5. For this test I am adding 250ml of tap water (equivalent to 250g) until the band snaps, this will be done at 1-minute intervals with the rubber band being measured as the water is added.
6. I Continue the process of adding to 250ml of water to the bucket, at 1-minute intervals and recording the length of the band until it snaps. I Ensure I am prepared for the band to snap with mats on the floor.

7. Clear up the work area when finished confirming all materials and equipment are returned to their rightful area.



Results

Test results				
Water (ml)	Length (mm)	Tension (gf)	Energy (J)	Force (N)
0	85	0	0	0
0	179	590	0.2720313	5.7879
250	235	840	0.2994012	8.2404
250	280	1090	0.4259925	10.6929
250	314	1340	0.4052511	13.1454
250	354	1590	0.574866	15.5979
250	369	1840	0.38774025	18.0504
250	388	2090	0.36625635	20.5029
250	403	2340	0.32593725	22.9554
250	416	2590	0.31436145	25.4079
250	430	2840	0.31436145	27.8604
250	442	3090	0.3490398	30.3129
250	456	3340	0.4415481	32.7654
250	462	3590	0.2039499	35.2179
250	468	3840	0.2186649	37.6704
250	473	4090	0.19448325	40.1229
250	486	4340	0.53753895	42.5754
250	488	4590	0.0876033	45.0279
250	491	4840	0.13876245	47.4804
250	498	5090	0.34094655	49.9329
250	504	5340	0.3069549	52.3854
250	507	5590	0.16083495	54.8379
250	0	5840		

Process Results				
Engineering strain	True strain	Cross sectional area (mm ²)	Engineering stress (N/mm ²)	True Stress (N/mm ²)
0	0	6.37	0	0
1.105882353	0.744734549	3.024860335	0.908618524	1.913443716
1.764705882	1.016934258	2.304042553	1.293626374	3.576496445
2.294117647	1.192138347	1.93375	1.678634223	5.529618617
2.694117647	1.306741729	1.724363057	2.063642072	7.623336596
3.164705882	1.426645657	1.529519774	2.448649922	10.19790673
3.341176471	1.468145388	1.467344173	2.833657771	12.30140844
3.564705882	1.518354083	1.395489691	3.21866562	14.69226189
3.741176471	1.556285305	1.343548387	3.603673469	17.08565186
3.894117647	1.588034004	1.3015625	3.988681319	19.52107563
4.058823529	1.621133952	1.259186047	4.373689168	22.12572167
4.2	1.648658626	1.225	4.758697017	24.74522449
4.364705882	1.679841553	1.187390351	5.143704867	27.59446375
4.435294118	1.692913635	1.171969697	5.528712716	30.0501797
4.505882353	1.705817039	1.156944444	5.913720565	32.5602497
4.564705882	1.716444132	1.144714588	6.298728414	35.05057106
4.717647059	1.743557367	1.11409465	6.683736264	38.21524499
4.741176471	1.747664149	1.109528689	7.068744113	40.58290738
4.776470588	1.753792871	1.102749491	7.453751962	43.05637898
4.858823529	1.767948821	1.087248996	7.838759812	45.92591043
4.929411765	1.779925012	1.074305556	8.223767661	48.76210472
4.964705882	1.785859747	1.067948718	8.60877551	51.34881393

Total cross-sectional area

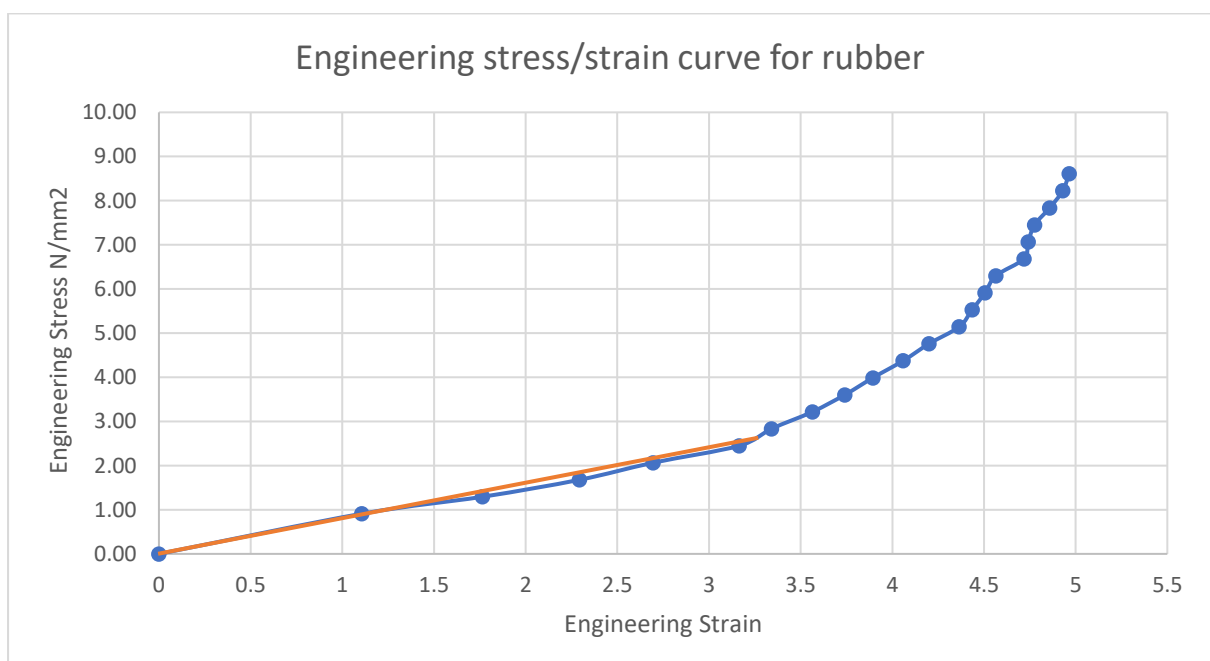
$$1.3 \times 2.45 = 3.185$$

$$3.185 \times 2 = 6.37 \text{ mm}^2$$

Total energy = 6.6665259

$$\text{Total Volume} = 85 \times 6.37 = 541.45 \text{ mm}^3$$

Graphs



At the initial stretch point from region of 0 to 3.25 I can see that the gradient of my line is constant, this shows that engineering stress is proportional to engineering strain in that area. As it is constant, I can work out the Young's modulus for this region. From the graph I can see that the stress is 2.5 N/mm^2 and the strain is 3.25. To find the Young's modulus:

$$3.25/2.5 = 1.3$$

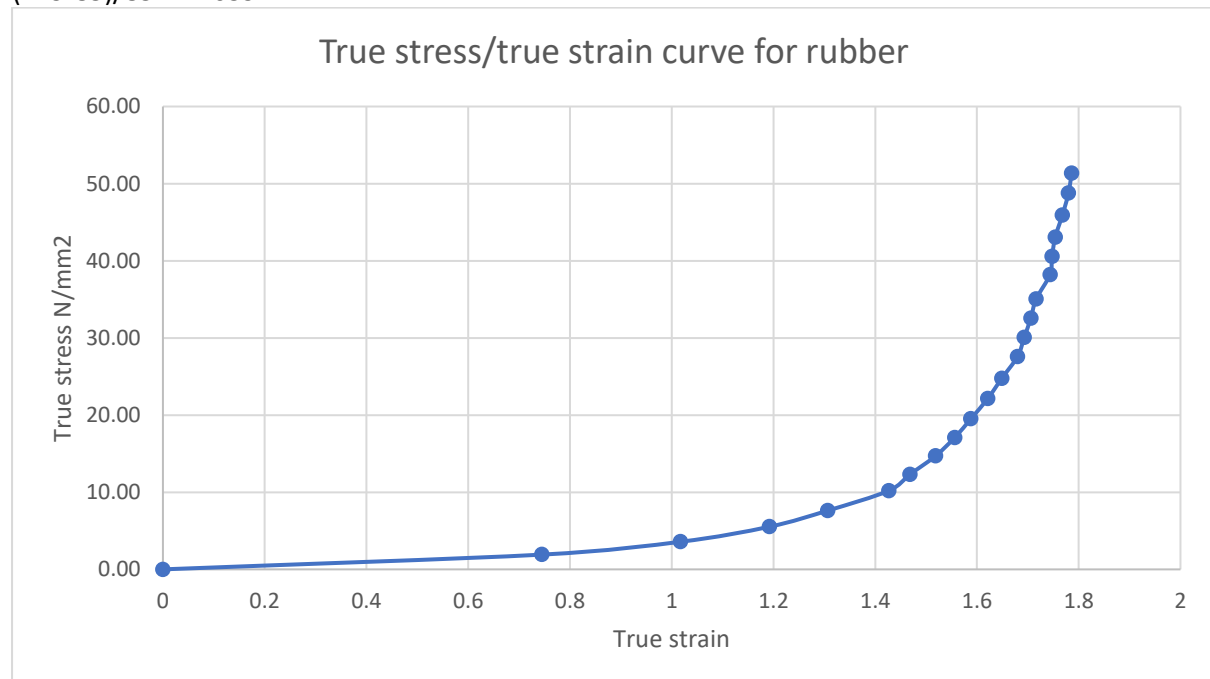
$$1.3 \times 10^6 = 1300000 \text{ N/mm}^2$$

To find the engineering stress I divided the force (N) by the original cross-sectional area with no force (mm^2) e.g.

$$5.7879/6.37 = 0.9086 \text{ N/mm}$$

To find the engineering strain I needed to find the current length minus the original length, then divide this by the original length e.g.

$$(179-85)/85 = 1.1059$$



From the true stress/strain curve we can see that the ultimate tensile stress is much higher compared to that on the engineering stress/strain. The true stress/strain graph shows the UTS as around 52 N/mm^2 but the engineering stress/strain graph shows a value around 8.75 N/mm^2 . The difference in values is because engineering stress is simplified as it disregards the cross-sectional change in the rubber band, but true stress correctly accounts for any changes in the cross-sectional area.

To find the values for true stress of the rubber band I divided the force by the new cross-sectional area e.g.

$$5.7879/3.0249 = 1.9134$$

The equation for true strain = $\sum \text{change in length}/\text{length}$ but integral calculus is needed for a true equation to represent true strain.

$$\epsilon_t = \int_{L_0}^{L_f} \frac{1}{L} dL$$

$$\epsilon_t = \left[\ln L \right]_{L_0}^{L_f}$$

$$\epsilon_t = \cancel{\ln}(L_f) - \cancel{\ln}(L_0)$$

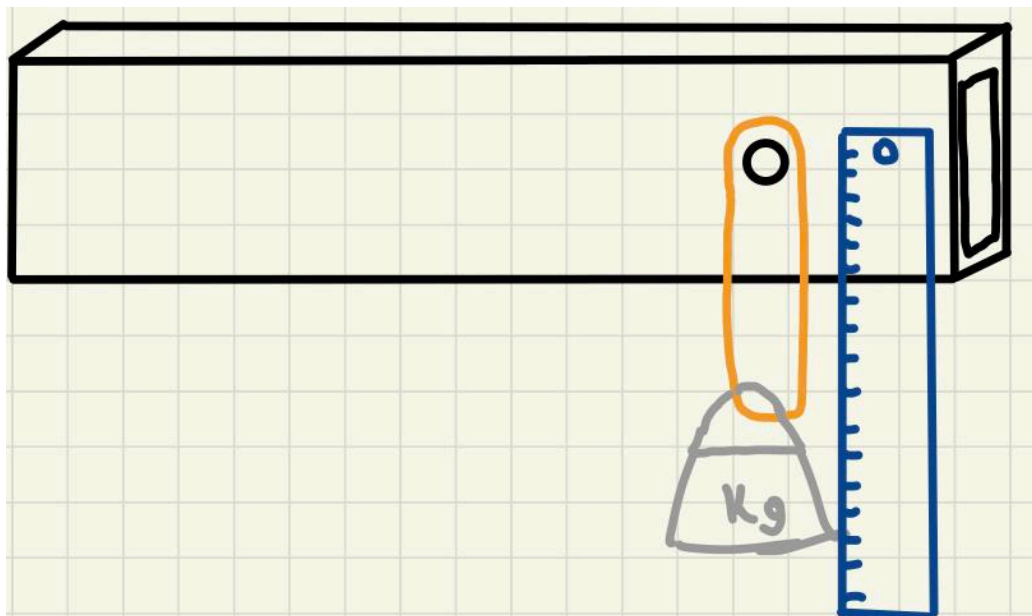
$$\epsilon_t = \ln \frac{L_f}{L_0}$$

$L_f = \text{final Length}$
 $L_0 = \text{Original Length}$
 $\ln = \text{Natural log}$

Using this equation, I can find the true strain values of the rubber band e.g.
 $\ln(179/85)=0.7447$

Analysis of experimental inaccuracy and cost/quality trade off

Looking back at my method and how my experiment was conducted one of the aspects I think could have been improved was my degree of accuracy with my measurements. For my experiment I used a tape measure for my measurements as it was the only measuring tool over 300mm which I owned, this I believe lead to rough measurement when measuring the length of the stretched rubber band. A more practical solution would have been to obtain a 1m rule and have it in a fixed position next to rubber band so I could get a clear reading of the length of the rubber band, similar to the sketch below.



Another inaccuracy in my experiment was the way I attached the rubber band to the bucket. I used a piece of shoelace and tied a loose knot between the bucket and the end of the band, doing this created a zone of higher stress at the end of the rubber band compared to the stress at the middle of band. With more time and money contributed to my experiment I would use recognised 'Dogbone' samples for my tensile test to get a stress/strain curve for rubber. 'Dogbone' samples are designed so the stress

concentration occurs in the centre when the sample is loaded with a force, this would lead to a higher degree of accuracy and more consistent results.

For my experiment I used water to apply the force to the rubber band. As explained in my method I used a water bottle to pour water into the bucket. Each time I weighed out the water using the scales then poured it out into bucket, but there is room for error in this method as I cannot be certain that all the water weighed out enters the bucket as drops could stay in the bottle. As you can see from my results, I poured water into the bucket from the bottle over 20 times this means my final force may be less than what I calculated, this is called a compounding error. With better resources, time and money I could have used a slotted mass set instead of the bucket with water in it, this way I would know exactly how much weight is being loaded onto the rubber band. Another alternative would be using a luggage scale to hang the rubber band from, this would ensure constancy with the water measured and the water that goes into the bucket.

Cost of experiment

- Rubber band- < 10p
- Tape measure - £3.50
- 400mm of 40x40 mild steel box section with hole drilled for hanging of rubber band - £2.97
- Tap water - £0
- Bucket x2 - £17.22
- Shoelace - £1
- Weighing scale – £0 (borrowed)
- G-clamp - £11
- M6 nut and bolt- < 10p
- Water bottle - £1.50
- Stopwatch - £3

Overall cost - £40.30

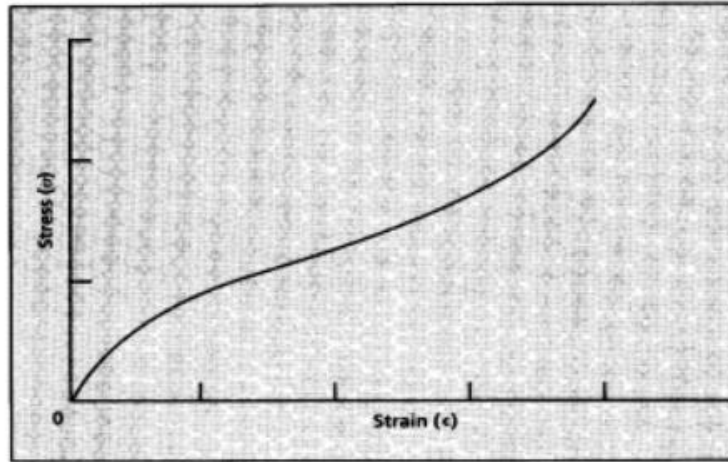
Through my research I found that a universal test machine can cost in the region of £20,000-£45,000. Looking at the price of my testing kit and the results I have produced I think that I have done a good job in replicating a tensile test for a rubber band.

Discussion

If I look back on my engineering stress/strain curve it followed the path that I expected it to, when I compare it to other graphs found online. As you could see from the graph at the initial stage it is harder to pull then at the middle phase it becomes easier then towards the ultimate tensile strength it becomes harder to stretch. This is because when a force is applied to rubber the stiffness progressively reduces and it becomes a lot easier to stretch, this is due to the chains inside the structure unravelling, once this has happened the rubber is much stiffer. With more time spent on this project I would be interested in looking into the elasticity property of rubber, for this I would take the rubber band to the point where it is about to snap (54.8379 N) and then start reducing the force to see how the molecules return to their original shape as they are attached to each other and return to its original length. Additionally, with more time and money I would have liked to investigate how temperature effects the stress/strain curve of rubber. As mentioned in my introduction I understand that rubber reacts differently compared to other materials as it contracts when heated, so I would have expected to see the rubber band snap under less force than 54.8379N, I would also expect the rubber not to stretch as much as it did at room temperature. I think a heat gun would be a good option to be able to complete this investigation or at a lower cost a hair dryer. Finally, with more time spent on this project I would have liked to have improved the reliability of my results, if I was to do this again, I would repeat my tensile test 5-6 times with identical rubber bands. From doing this I would get a mean result for my values.

Conclusion

In conclusion of this assignment, I would regard my experimental method as a success, I was able to gather results to plot a true stress/strain graph and an engineering stress/strain graph that were similar to those published online by recognised material scientists, for example Daniel L. Hertz Jr who was renowned for his work in the rubber industry.



(Engineering stress/strain graph from Daniel L. Hertz Jr)

From my stress strain graph, I was able to find Young's modulus for engineering stress/strain which I believe to be 1300000 N/mm^2 . My results also correlate with the theory of elastomer behaviour that when a force is applied to rubber the stiffness progressively reduces and it becomes a lot easier to stretch, this is due to the chains inside the structure unravelling, once this has happened the rubber is much stiffer. As mentioned, I believe there were some improvements that could have been made with my experiment with more time and money for example, a new way of measuring the length of the rubber, repetition of the experiment, a better designed sample, and an improved way of adding force to the sample. But in reflection I think my method and design of this experiment has given me a great understanding of the properties and structure of rubber.

Acknowledgement

I would like to recognise Chris Wyatt for his help in me completing this assignment. I also thank my workplace (Swansea University) for letting me use their workshop space and borrowing their weighing scale to complete the practical aspect of this assignment.

References

- engineering materials (tensile testing of rubber, metals and alloys)* (2019) *StuDocu*. Dundalk institute of technology . Available at: <https://www.studocu.com/en-ie/document/dundalk-institute-of-technology/structural-mechanics-1/82310035-engineering-materials-tensile-testing-of-rubber-metals-and-alloys/10744485> (Accessed: November 8, 2022).
- 2 rubber stress-strain behavior - ingénieur-buch.de* (no date) *Rubber Stress-Strain Behavior*. Available at: https://www.ingenieur-buch.de/media/blfa_files/9783446416819-Leseprobe.pdf (Accessed: November 9, 2022).
- Barratt, H. (no date) *Sources of variation, its measurement and Control, Sources of variation, its measurement and control | Health Knowledge*. Available at: <https://www.healthknowledge.org.uk/public-health-textbook/research-methods/1a-epidemiology/sources-variation-measurement-control> (Accessed: November 12, 2022).
- Callister, W.D. (no date) “Chapter 14 - Molecular structures ,” in D.G. Rethwisch (ed.) *Materials science & engineering* . 8th edn. Wiley.
- Craig Freudenrich, P.D. (2020) *How rubber works, HowStuffWorks Science*. HowStuffWorks. Available at: <https://science.howstuffworks.com/rubber2.htm#:~:text=These%20long%20strands%20are%20called,poles%20of%20two%20bar%20magnets.> (Accessed: November 7, 2022).
- Heath Robinson Material properties experiment* (2020) *YouTube*. YouTube. Available at: <https://www.youtube.com/watch?v=nro1zN2zuOo&t=1749s> (Accessed: November 14, 2022).
- Hertz jr, D.L. (no date) *Elastomerics- Rubber under strain: an engineering approach , An analysis of rubber under strain from an engineering perspective*. Available at: <https://www.sealseastern.com/PDF/RubberUnderStrain.pdf> (Accessed: November 12, 2022).
- Lachica, L. (2020) *Making dogbone tensile test samples , TestResources*. Available at: <https://www.testresources.net/blog/making-dogbone-tensile-test-samples/> (Accessed: November 11, 2022).
- Lewis (2017) *Behaviour of rubber - A level physics, YouTube*. YouTube. Available at: <https://www.youtube.com/watch?v=cZtmvv4R57w> (Accessed: November 2, 2022).
- QuantumBoffin (2009) *Stretching an elastic band, YouTube*. YouTube. Available at: <https://www.youtube.com/watch?v=fFtM9JznLh8> (Accessed: November 1, 2022).
- Rubber* (no date) *Rubber - A-level physics revision*. Available at: <https://revisionworld.com/a2-level-level-revision/physics/force-motion/solid-materials/rubber> (Accessed: November 10, 2022).

