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1. Introduction

Within a competitive motorsport scene specifically the Dakar rally, a failed scenario has been proposed. Two vehicles have endured a catastrophic malfunction within the drive shafts, resulting in immediate loss of power rendering the vehicle in a stationary state.

The purpose of this project is to investigate the main causes of why the drive shaft has failed through engineering analysis and practical experimental testing. The vital objective of this project is to:

- Perform a practical tensile test of the sample provided
- Analyse the practical data to calculate Young's modulus, yield strength, and ultimate tensile strength
- Hypothesise the potential causes responsible for the failed component based on gathered evidence
- Provide potential safety measures to prevent similar causes from occurring

2. Literature review

2.1.1 Aluminium properties

A notable feature of aluminium is its low density, in terms of utilizing it in drive shaft designs it significantly reduces its rotational inertia which leads to overall improvement in its acceleration response and overall vehicle efficiency, which plays a significant role in endurance rallying as these vehicles are subjected to varying terrains, fluctuations in speed and load. Lighter driveshaft reduces energy demand on the powertrain, which is favorable in the endurance aspect (Clausen, 2009).

In comparison to other materials aluminium has a low young's modulus of 70 Gpa this value may vary depending on the alloy (Wilson, 2025) the favored property of it being less stiff compared to steel is essential in drive shaft designing because stiffness can affect angular twist under torque, alignment of drivetrain components and vibration response. Unfortunately, when using materials with lower stiffness the risk of excessive deformation increases which means within the Dakar conditions, where shock loading is frequent the reduced stiffness accelerates fatigue damage. A specific study (Ikechukwu, 2013) portrays stiffness directly impacts torsional behavior and buckling resistance.

Aluminium naturally forms a protective coating but within the harsh conditions in Dakar, various elements like sand, moisture, and dust can prevent the coating from working known as localized corrosion. This is where corrosion fatigue kicks in, the interaction amongst the corrosion and cyclic loadings highlights failures within aluminium components. These studies reiterate that the real world conditions are much more complex meaning environmental degradation must be considered within simulations (Zihchil, 2025).

2.1.2 Test methods

Firstly, the hardness test a method using the Brinell or Vickers. Which provides an overview of the aluminium's resistance to indentation. This can be used to evaluate how resistant aluminium is to localized plastic deformation which is an irreversible strain within crevices. This method can be carried out by pressing a solid indenter onto the surface applying a controlled load then measuring the depth of the indentation that is left behind (Newage hardness testing, 2026). Hardness testing has its limitations, it only measures the surface properties, and it does not have a full overview of how the material will behave under varying load conditions such as torsion.

Furthermore, the next test will be for its strength and ductility which describes how the material will behave under load. The most common way to assess the stated properties is through a tensile test, within the tensile test the specimen is held at both ends and pulled apart until eventually reaching breaking point. This test produces a stress strain curve, this is essential as it records the initial elastic deformation all the way through the permanent plastic deformation until eventually failing (TecQuipment Ltd, 2012).

Additionally, another test method is high cycle fatigue/fatigue testing. This test is used to discover the material's behaviour under repeated, low to moderate loading. The outcome for this test is to determine how long a material can withstand the repeated loads before failure. Particularly essential for the Dakar rally where endurance is key for the automotive components as they endure varying loads and vibrations (Nicholas, 2006).

3. Methodology

3.1.1 Setup

Initially, an experimental setup must be constructed in order to carry out the test. The setup consisted of a work back panel and the tensile tester, assembled to ensure stability and accurate load application. To guarantee that the setup is constructed properly figure 3.1 portrays an accurate representation of how the setup must look like. To begin constructing the setup the work panel must be mounted onto the support beams with the use of two thumbscrews on each side provided within the box. Once the work panel is securely fixed, attach the tensile tester onto the work panel firmly to avoid any movement during the testing phase.

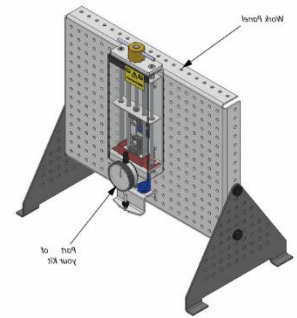
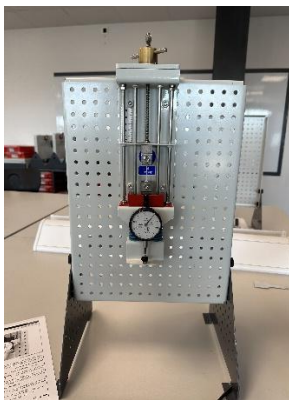


Figure 3.1: Constructed work panel.



The tensile tester consists of various notable features that are essential such as the load nut, vertical scale, top plate, and the dial indicator. To fit in the testing specimen, use an allen key to undo the two allen key bolt allowing the specimen to be placed into the top and bottom chuck. The load nut at the top of the tensile tester allows the tester to raise the upper chuck pulling the specimen upward by 1mm for each complete turn. On the load nut there are notches, it is a scale that indicates how far the tester has turned the control arm on each turn. Within the apparatus also resides a dial indicator, the dial indicator measures spring deflection when forces are being applied. When working with the dial indicator ensure to zero it carefully striving for a precise and accurate reading, to do so turn the load nut in a clockwise manner until the reading fluctuates and that the notch points to one of the ten marks of its scale.

3.1.2 Experimental procedures

To start the experiment, ensure to have the correct specimen and make sure it is free from visible defects such as chipping, bending or any form of surface damage as these could act as stress concentrators which can affect result outcomes. Utilizing a dial caliper, measure different dimensions of the specimen, specifically thickness and width at the gauge length as it is required for later calculations.

After recording the different dimensions of the specimen, securely mount the specimen into the tensile tester apparatus ensuring correct alignment to avoid bending stresses, then ensure to accurately zero the dial indicator for valid results.

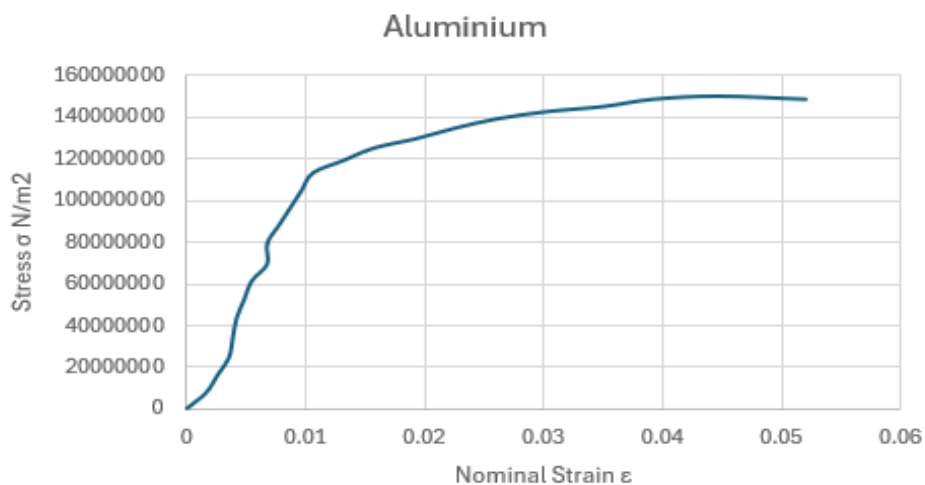
Furthermore, after doing so to fill in the required data that is missing within the handout, gradually apply load by turning the load nut clockwise in increments of 0.2 mm which is equivalent to two notches within the nut scale. At each increment ensure to record the measurement provided on the indicator reading scale, which represents the materials response. After each adjustment to increase accuracy within the readings wait approximately two to five seconds allowing the tester to stabilise avoiding any form of anomalies.

The process is then repeated, ensuring consistent increments and accurate readings at each stage. Repeat this process until the specimen reaches its breaking point. At the breaking point it is essential to record the final load as it determines properties such as its yield strength, its ultimate tensile strength etc.

After the test is completed, remove the broken specimen and carefully push them back together at the fracture point this allows the tester to measure its final length. This allows the elongation value to be calculated.

4. Lab results

Main Data Table		:Aluminium			
Load Nut Movement (mm)	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress σ N/m ²	Nominal Strain ϵ
0	0	0	0	0	0
0.2	0.15	15	0.05	7500000	0.001607717
0.4	0.32	32	0.08	16000000	0.002572347
0.6	0.49	49	0.11	24500000	0.003536977
0.8	0.68	68	0.12	34000000	0.003858521
1	0.87	87	0.13	43500000	0.004180064
1.2	1.05	105	0.15	52500000	0.004823151
1.4	1.23	123	0.17	61500000	0.005466238
1.6	1.39	139	0.21	69500000	0.006752412
1.8	1.59	159	0.21	79500000	0.006752412
2	1.76	176	0.24	88000000	0.007717042
2.2	1.93	193	0.27	96500000	0.008681672
2.4	2.1	210	0.3	105000000	0.009646302
2.6	2.27	227	0.33	113500000	0.010610932
2.8	2.39	239	0.41	119500000	0.01318328
3	2.51	251	0.49	125500000	0.015755627
3.2	2.6	260	0.6	130000000	0.019292605
3.4	2.7	270	0.7	135000000	0.022508039
3.6	2.79	279	0.81	139500000	0.026045016
3.8	2.86	286	0.94	143000000	0.03022508
4	2.91	291	1.09	145500000	0.035048232
4.2	2.98	298	1.22	149000000	0.039228296
4.4	3.01	301	1.39	150500000	0.044694534
4.6	2.98	298	1.62	149000000	0.052090032
4.8					
5					
6					
7					
8					
9					
10					
20					
30					
40					
50					
60					



5. Analysis

Within the paper that was provided resides an empty table, load nut movement were predetermined values to be followed during the experiment. The following column is the dial indicator, these values were collected during the practical experiment and recorded by observing the indicator attached on the tensile tester.

To calculate the next column, applied force measured in newtons (N), multiply the dial indicator values by the combined spring rate of the apparatus which has a value of 100N/mm.

The following column is determined by using the measurements gathered from the tensile testing equipment. By subtracting the dial indicator values from the number of the load nut movement. This can be expressed as:

$$\text{Extension (mm)} = \text{Number of turns of force control (mm)} - \text{Dial indicator reading (mm)}$$

Elongation value is the difference between the final length and original length

Stress values were calculated using the applied force values and the nominal cross sectional area of the specimen with a value of 2×10^{-6} , To calculate stress the following formula must be applied F/A where F is force and A is the nominal value for the cross section.

Then strain values can be calculated by utilizing the following formula l/L where l is change in length divided by the original length which was measured to be 31.1mm

The experimental result that was gathered during the tensile test portrays, within the initial stages of the experiment stress-strain were increasingly linear to one another where Hooke's law still applied (TecQuipment Ltd, 2012). Unfortunately, the curve becomes nonlinear at a rapid rate indicating as stress strain gradually passes the yield point the material is experiencing plastic deformation where the state of the material is no longer reversible.

Furthermore, after state of plastic deformation, stress-strain gradually keeps increasing where strain increases more rapidly relative to stress. Within the strain hardening state where the material becomes stronger through deformation but ductility deviates as a trade of. Stress reaches a maximum value of 150 Mpa portraying the specimen's ultimate tensile strength before failure.

6. Conclusion

The cause of the failure within the driveshaft could potentially be linked to high cycle fatigue, as the proposed operation stress of approximately 90 Mpa lies below the experimental determined value for yield strength of the sampled material.

This indicated that the automotive component did not malfunction to a single overload event but rather experienced an repeated cyclic loading, leading to a progressive crack and overtime expanding. The conditions within the Dakar rally would have expedited the already fatigued damage, the terrain of Dakar would also have a significant impact along with continuous rotational loading, varying speed loads, and vibrations. (Nicholas, 2006)

The tensile test provided an insightful evaluation of the material's property including its ductility, strength, and elastic behaviour. Though the experiment has its limitations, it does not fully replicate real life conditions for a drive shaft, as the experiment does not apply varying load conditions, torsion etc. To mitigate the risk from occurring again, the material grade and heat treatment should be verified.

7. References

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