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# **Driveshaft Failure Report**

**ACHA4025 Engineering Materials**

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## Contents

|                                                                      |    |
|----------------------------------------------------------------------|----|
| 1. Introduction.....                                                 | 1  |
| 2. Literature Review .....                                           | 2  |
| 3. Methodology .....                                                 | 4  |
| 4. Test Results.....                                                 | 7  |
| 5. Analysis.....                                                     | 9  |
| 6. Conclusions .....                                                 | 11 |
| 7. References.....                                                   | 12 |
| <br>                                                                 |    |
| Figure 1 - Tensile Testing Equipment from ES6 Kit .....              | 4  |
| Figure 2- Tensile Tester Parts, TecQuipment Ltd., (2012) .....       | 5  |
| Figure 3 - Stress Strain Graph for Calculating Young's Modulus ..... | 10 |
| Figure 4 - Driveshaft Failure, Rogers, K. (2026) .....               | 11 |
| <br>                                                                 |    |
| Table 1 - Tensile Test Results .....                                 | 7  |
| Table 2 - Final Calculations .....                                   | 9  |

## 1. Introduction

The Dakar Rally is a gruelling challenge for any vehicle due to the distance involved and the rough terrain that the vehicles must endure, (TOYOTA MOTOR CORPORATION, 2026). Vehicles have to be built to be incredibly strong while minimising the weight to help improve their competitiveness.

There has been a repetitive fault found with the aluminium driveshafts. The supplier for the aluminium has recently been changed and so the fault is strongly suspected to be a problem with the material.

This project has been tasked with finding a suitable solution for the failing driveshafts, to prevent the issue from happening again in the future. The stress and strain, as well as the Young's Modulus of the current material needs to be determined first, in order to get a baseline from which to improve on. The weight must be kept to a minimum to keep the vehicle competitive in the sport, but must be able to withstand everything that's thrown at it. The driveshafts must be able to handle the external factors as well as being able to transmit the engine's power and torque to the wheels, without breaking.

## 2. Literature Review

The driveshafts that failed were made from aluminium. Given that the failure appears to be due to fatigue, **tensile testing** is an important test to help find a suitable material for the driveshafts. Tensile testing is covered in more detail in the Methodology section. In short, it works by pulling a sample apart to measure how much it extends by before it fails, (Industrial Metallurgists, 2022), in order to determine the Yield stress, the Ultimate Tensile stress and the Young's Modulus.

It may be prudent to carry out a **toughness test** on the material too, as the Dakar Rally involves very rough terrain with lots of rocks and sand. The driveshafts will be exposed to impacts from all the debris as it's flicked up. This could lead to impact damage. This test is performed by placing a sample, with a notch in it, in a special device which strikes it with a hammer-like tool. It measures how much energy is absorbed by the sample, allowing the toughness to be determined, (MacKenzie, Ph.D. and FASM, 2020).

**Torsional testing** should be carried out to ensure that the material can cope with the torques that will be applied to it, without failing. This test is carried out by placing a sample into a special chuck and applying a rotational torque until the sample fails, (Metallurgical Engineering Services, 2025). This measures the torque and the angular displacement in order to calculate strength and elasticity values.

**Fatigue testing** should be carried out to see the effects of fatigue on the sample. The sample is required to survive many cycles of loading and unloading, to make sure it can last the required lifespan of the part. In motorsport, parts often only need to survive the length of the event. For driveshafts, torsional fatigue testing would be the most relevant. This test is performed in a similar way to the torsional test, but this one runs through many cycles of applying high or low torque for a set number of cycles, or until it breaks, (STEP Lab, n.d.). It looks for any twisting and vibrations.

**Hardness testing** should be completed to make sure the part will not wear out prematurely and to determine the best heat treatments for the part. This is done by placing a flat sample into the machine and pressing an indenter into the sample with a set load. The harder the material the smaller the indentation will be. The indentation is then measured to determine the hardness value, (www.aybu.edu.tr, n.d.).

**Ultrasonic testing** can be used to look inside a part to find any defects that cannot be identified visually. This is done in a non-destructive way, reducing the costs and wastage of materials due to testing. This could be used on the finished part to ensure it is free of defects and between events to try find defects as they arise in an ongoing development process. This could be done by using a probe on either side of the part, one a transmitter, the other a receiver. The received signal is analysed to determine if and where there are any defects in the part, (Dukowitz, 2024).

### 3. Methodology

The tensile testing was carried out using the tensile tester found in the ES6 kit. The kit should be assembled as seen in figure 1 below.

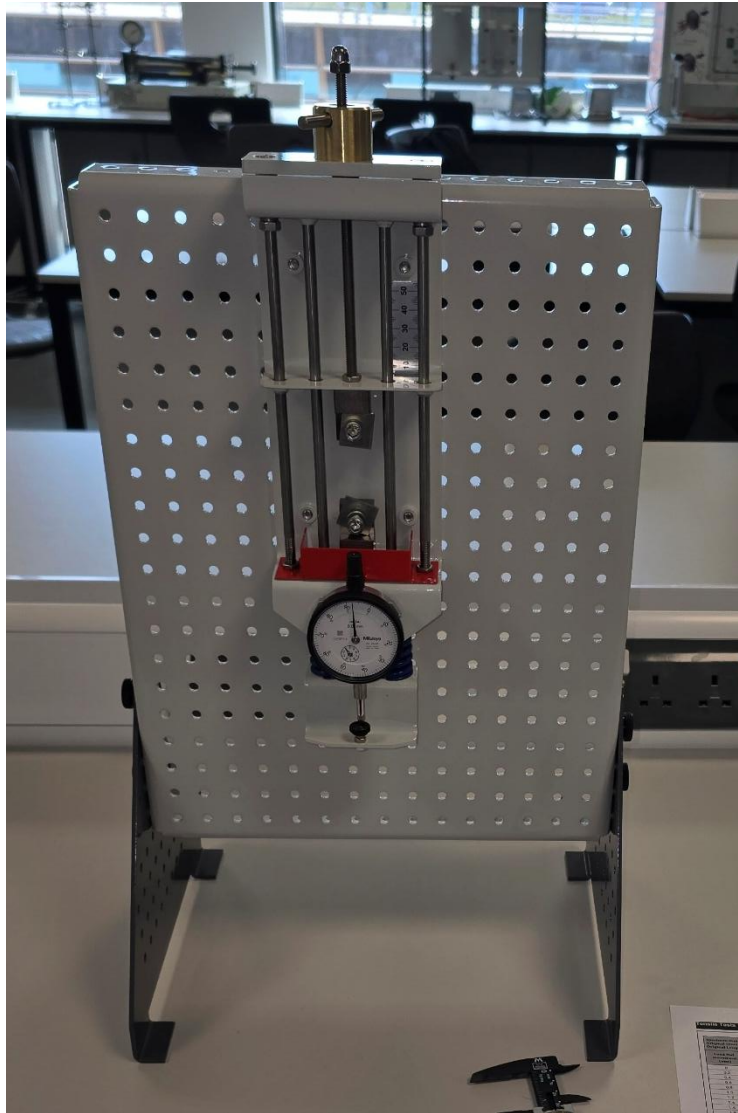


*Figure 1 - Tensile Testing Equipment from ES6 Kit*

Figure 2 shows the various parts of the apparatus and the names of each.

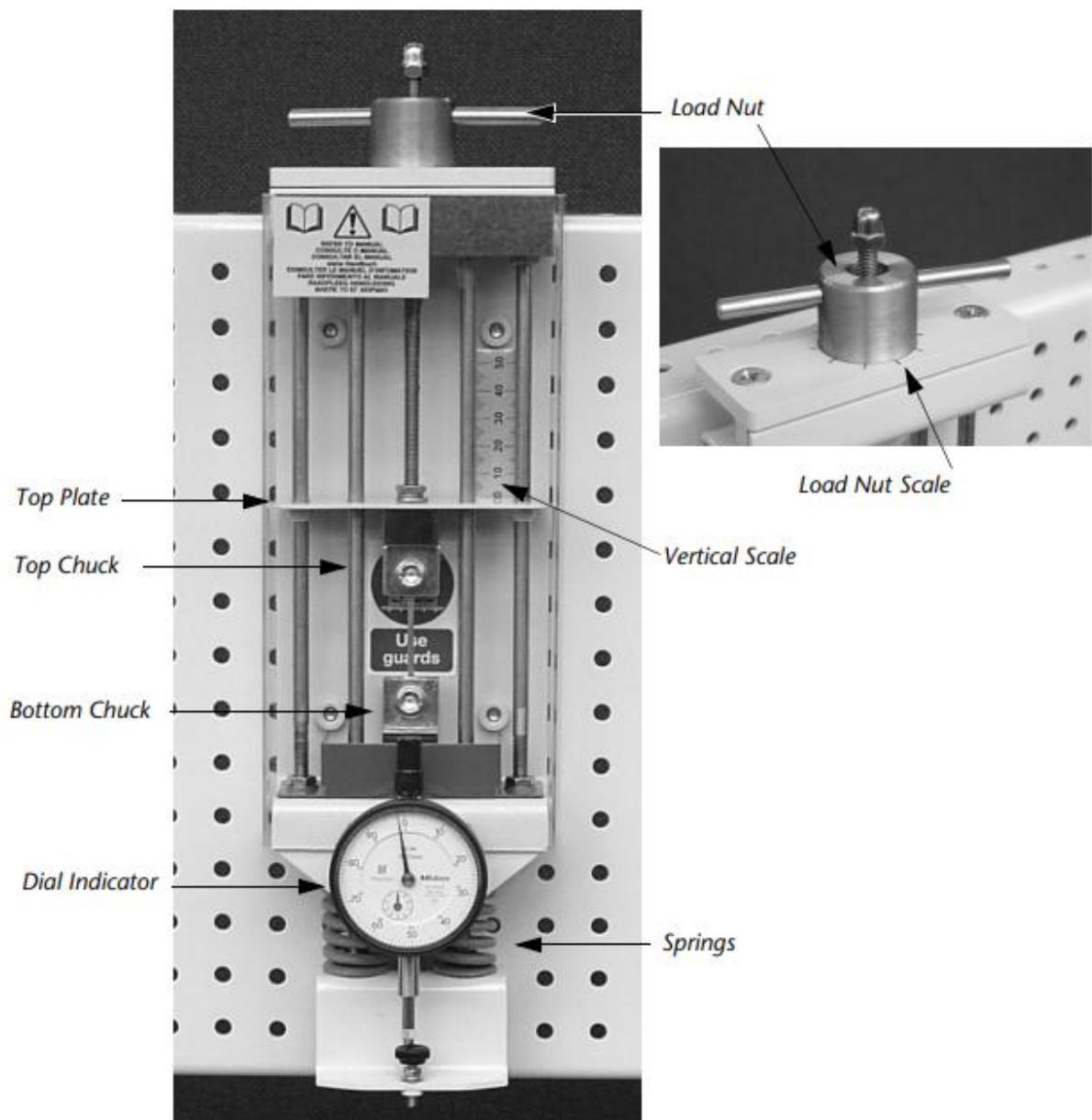


Figure 2- Tensile Tester Parts, TecQuipment Ltd., (2012)

The test procedure is as follows;

- Measure the original length of the sample for testing.
- Fit the sample in between the top and bottom chucks.
- Fit the safety guard.
- Adjust the load nut to take up the strain and line up the marking on the side of the load nut with the closest marking around it.
- Zero the Dial indicator.

- Start turning the load nut 1 marking at a time, noting the dial indicator reading.
- At 2.5mm on the load nut, start turning the load nut 1 full revolution and taking the dial indicator's reading.
- Continue until the sample breaks, stopping immediately.
- Remove the safety guard.
- Remove the sample from the chucks.
- Measure the final length of the sample.

## 4. Test Results

Below is the table of results from the tensile test on the aluminium sample.

Table 1 - Tensile Test Results

| Load nut movement (mm) | Dial indicator (mm) | Force (N) | Extension (mm) | Stress (Mpa) | Nominal Strain |
|------------------------|---------------------|-----------|----------------|--------------|----------------|
| 0                      | 0                   | 0         | 0              | 0            | 0              |
| 0.1                    | 0.04                | 4         | 0.06           | 2000         | 0.001935484    |
| 0.2                    | 0.12                | 12        | 0.08           | 6000         | 0.002580645    |
| 0.3                    | 0.21                | 21        | 0.09           | 10500        | 0.002903226    |
| 0.4                    | 0.3                 | 30        | 0.1            | 15000        | 0.003225806    |
| 0.5                    | 0.39                | 39        | 0.11           | 19500        | 0.003548387    |
| 0.6                    | 0.48                | 48        | 0.12           | 24000        | 0.003870968    |
| 0.7                    | 0.57                | 57        | 0.13           | 28500        | 0.004193548    |
| 0.8                    | 0.66                | 66        | 0.14           | 33000        | 0.004516129    |
| 0.9                    | 0.75                | 75        | 0.15           | 37500        | 0.00483871     |
| 1                      | 0.84                | 84        | 0.16           | 42000        | 0.00516129     |
| 1.1                    | 0.93                | 93        | 0.17           | 46500        | 0.005483871    |
| 1.2                    | 1.03                | 103       | 0.17           | 51500        | 0.005483871    |
| 1.3                    | 1.12                | 112       | 0.18           | 56000        | 0.005806452    |
| 1.4                    | 1.21                | 121       | 0.19           | 60500        | 0.006129032    |
| 1.5                    | 1.3                 | 130       | 0.2            | 65000        | 0.006451613    |
| 1.6                    | 1.4                 | 140       | 0.2            | 70000        | 0.006451613    |
| 1.7                    | 1.49                | 149       | 0.21           | 74500        | 0.006774194    |
| 1.8                    | 1.58                | 158       | 0.22           | 79000        | 0.007096774    |
| 1.9                    | 1.66                | 166       | 0.24           | 83000        | 0.007741935    |
| 2                      | 1.75                | 175       | 0.25           | 87500        | 0.008064516    |
| 2.1                    | 1.84                | 184       | 0.26           | 92000        | 0.008387097    |
| 2.2                    | 1.92                | 192       | 0.28           | 96000        | 0.009032258    |
| 2.3                    | 2.01                | 201       | 0.29           | 100500       | 0.009354839    |
| 2.4                    | 2.1                 | 210       | 0.3            | 105000       | 0.009677419    |
| 2.5                    | 2.19                | 219       | 0.31           | 109500       | 0.01           |
| 3.5                    | 2.81                | 281       | 0.69           | 140500       | 0.022258065    |
| 4.5                    | 3.19                | 319       | 1.31           | 159500       | 0.042258065    |

The load nut movement and dial indicator columns are taken from the tensile test measurements.

The other columns need to be calculated.

The Force column was calculated simply by multiplying the dial indicator values (DI) by 100. This is described in the Engineering Science Guidance Notes: Tensile Tester ES6 Kit, TecQuipment Ltd. (2012).

$$F = DI * 100$$

The Extension ( $\delta L$ ) column was calculated by subtracting the dial indicator values (DI) from the load nut movement values ( $LN_m$ ).

$$\delta L = LN_m - DI$$

The Stress column was calculated by dividing the force (F) values by the cross-sectional area (A).

$$\sigma = \frac{F}{A}$$

The Nominal Strain ( $\epsilon_N$ ) column was calculated by dividing the extension ( $\delta L$ ) by the original length ( $L_o$ ).

$$\epsilon_N = \frac{\delta L}{L_o}$$

## 5. Analysis

Below are the values calculated using the data from the test and table 1.

Table 2 - Final Calculations

| Ultimate Tensile Strength (N/mm <sup>2</sup> ) | Yield Stress (N/mm <sup>2</sup> ) | % Elongation | Young's Modulus of Aluminium (Gpa) |
|------------------------------------------------|-----------------------------------|--------------|------------------------------------|
| 159500                                         | 109500.00                         | 4.23%        | 13950                              |

The Ultimate Tensile Strength (UTS) was calculated by dividing the Extension ( $\delta L$ ) by the Cross-Sectional Area (A). The UTS was calculated to be 159500N/mm<sup>2</sup>.

$$UTS = \frac{\delta L}{A}$$

The Yield Stress was read off the graph as the Yield stress is the maximum stress that can be taken before the sample would deform plastically (permanently). The Yield Stress value was found to be 109500N/mm<sup>2</sup>.

The Elongation percentage ( $\delta L\%$ ) was calculated by subtracting the final length ( $L_F$ ) from the original length ( $L_O$ ) and dividing that by the original length. The Elongation percentage value was calculated to be 4.23%.

$$\delta L\% = \frac{(L_F - L_O)}{L_O}$$

Using the stress and strain values, the graph below was created to help determine the Young's Modulus of the sample. This was determined in Excel by using the slope function.

$$E = SLOPE \frac{(E5:E9, F5:F9)}{1000}$$

The above formula relates to points on the elastic deformation region of the graph, the near linear section of it. The points used were between 6000 and 24000MPa. This region was used as there were some anomalies which made the top of the elastic region on the graph look a little bumpy. The Young's Modulus was found to be 13950GPa. This can be seen in table 2 above, along with all the other values.

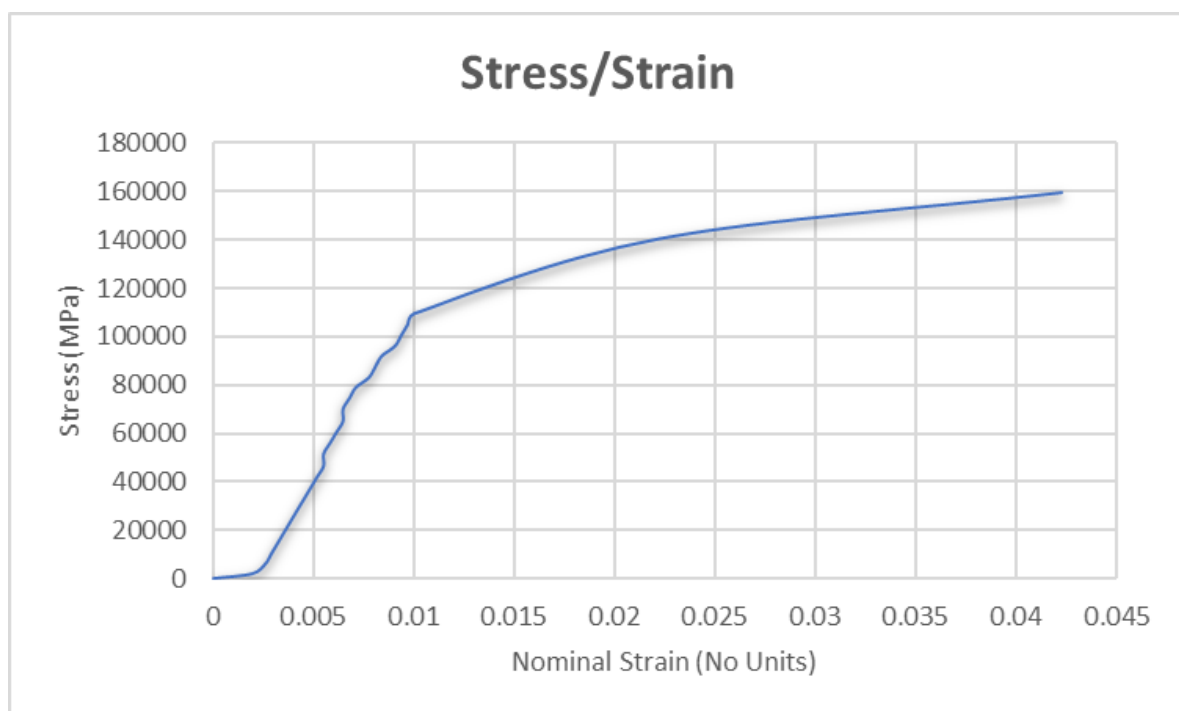


Figure 3 - Stress Strain Graph for Calculating Young's Modulus

## 6. Conclusions

Looking at the image of the failure point of the driveshaft, there are clear signs that the failure was a result of fatigue. There is a relatively smooth area in a crescent moon shape, which may have striations on it, though they're difficult to see in the image. The rest of the surface is rough, as a result of the load finally overcoming the remaining material, causing it to fail quickly by snapping.

It is difficult to determine the shape of the area where the failure initially propagated, but it could be caused by poor design, material defects or limitations, or overloading. The maximum stress on the driveshaft was measured to be 90MPa.



*Figure 4 - Driveshaft Failure, Rogers, K. (2026)*

This could be rectified by increasing the diameter of any fillets to eliminate stress concentrators, increase the thickness of the driveshaft, where possible and by using a higher grade of aluminium. Even simply returning to the previous aluminium supplier would likely solve the problem.

Another solution would be to change the material used to make the driveshaft from. In this case, a titanium alloy would be a very good substitute, especially in a challenging and rugged motorsport such as the Dakar Rally. This is due to the material's fatigue limit, which is around 50 and 60% of its ultimate tensile strength. That means that if the maximum load is kept below that level, then the material can, in theory, endure an infinite number of cycles, virtually removing the risk of fatigue failure. That is providing that the cycle frequency doesn't get too high, otherwise it will fail from fatigue at some point. Given the highest stress measured was 90MPa, the fatigue limit would need to be 180MPa or above. Titanium alloys can have a fatigue limit of 500 to 700MPa, making it unlikely it would suffer from fatigue.

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