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Engineering Materials

Materials and Manufacturing (ACHA4025)

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Date (04/2026)

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1. Introduction

The purpose of this report is to identify the root cause of a mechanical failure on two Dakar cars. To do this, an experiment will be undertaken where the tensile strength of aluminium samples is measured. From this the yield strength, ultimate tensile strength, and Young's modulus will be calculated. The data will then be evaluated against expected figures for similar materials. Using this data, potential remedies for the failure will be presented and evaluated.

2. Literature review

2.1 Strength

Strength refers to a material's ability to withstand applied stresses without breaking, deforming, or failing. It is one of the most important properties considered in the design of components and structures, as it ensures materials can safely and reliably perform their intended functions under continuous loads and helps prevent issues such as material creep. Material strength is evaluated using tensile, compression, and stress-strain testing to determine how it responds under different loading conditions. These tests provide key properties such as yield strength, ultimate strength, and deformation behaviour which is vital when dealing with Dakar driveshafts.

2.2 Fatigue Limit

The fatigue limit, or endurance limit, describes the highest level of stress a material can endure repeatedly over an infinite number of cycles without experiencing failure. This is a critical consideration because many components operate under repeated loads, where damage can accumulate over time even if the applied stress is much lower than the material's ultimate tensile strength. By understanding a material's fatigue limit, engineers can design components that maintain long-term durability and reliability, particularly in automotive applications such as the Dakar cars. Fatigue testing subjects a specimen to repeated cyclic loading at different stress levels until failure occurs. The results are used to produce S-N curves, which relate stress to cycles to failure and allow prediction of fatigue life.

2.3 Toughness

Toughness is the ability of a metal to deform plastically and to absorb energy in the process before failure. To ensure good toughness its best to have a combination of ductility and strength. This is important when it comes to the Dakar cars as its usually better for parts to bend and absorb energy rather than just breaking. It can usually be measured by putting stress against strain resulting from a tensile test.

2.4 Ductility

Ductility is the ability of a material to withstand significant plastic deformation under tensile loading before fracture, and it is commonly measured by percentage elongation obtained from a tensile test. In Dakar, ductility is critical because it allows structural materials to deform and absorb energy during impact. Ductility is typically tested using a standard tensile test which helps determine elongation and necking behaviour as indicators of ductile performance.

2.5 Microstructure

Microstructure refers to the internal structure of a material at the microscopic scale, including its grains, phases, grain boundaries, and defects, all of which influence mechanical behaviour such as strength, toughness, and fatigue performance. Dakar, microstructure is critical because it directly governs how materials deform and absorb energy, durability, and the performance of lightweight structural components.

Microstructure is commonly characterised using techniques such as Electron Backscatter Diffraction (EBSD) in a scanning electron microscope, where a polished crystalline sample is analysed to generate orientation maps that reveal grain structure, phase distribution, and boundary characteristics.

3. Methodology

For this test a tensile tester and an aluminium specimen were used. The tensile testing equipment was attached to a work panel. To start the test the Aluminium specimen was fitted into the testing equipment using the two chucks. With the specimen fitted the next step was to slowly turn the force control clockwise until slight movement was seen on the dial, at which point the dial was zeroed. From this point the load nut was turned 180 degrees (0.2mm movement) and the first measurement was taken. This was repeated until the specimen broke at 25 half rotations (5mm).

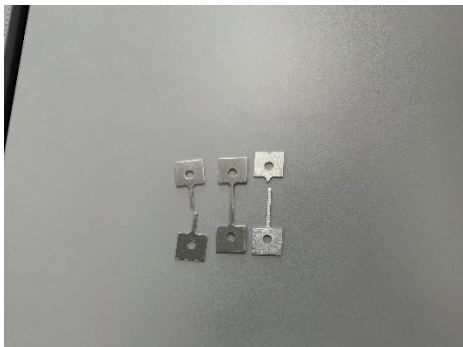


Figure 1, Photograph showing broken specimens.

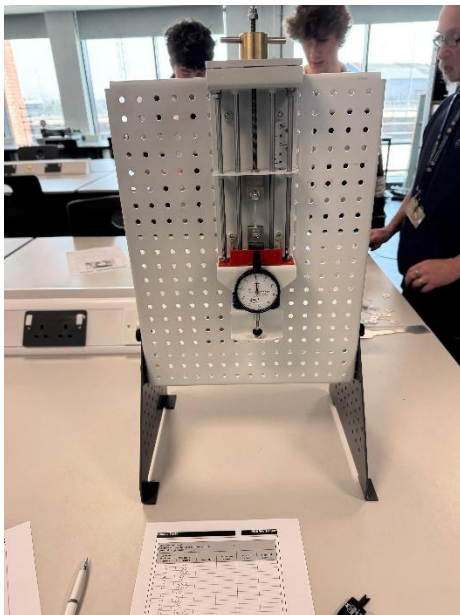


Figure 2, Photograph showing the testing equipment.

4. Test Results

Table 1, Table of raw and calculated results from the test.

Load Nut Movement (mm)	Dial Indicator	Dial Indicator (mm)	Force (N)	Extension (mm)	Stress σ N/m ²	Nominal strain ϵ
0	0	0	0	0	0	0
0.2	15	0.15	15	0.05	7500000	0.001724
0.4	32	0.32	32	0.08	16000000	0.002759
0.6	49.5	0.495	49.5	0.105	24750000	0.003621
0.8	67	0.67	67	0.13	33500000	0.004483
1	85	0.85	85	0.15	42500000	0.005172
1.2	104.5	1.045	104.5	0.155	52250000	0.005345
1.4	123.5	1.235	123.5	0.165	61750000	0.00569
1.6	141	1.41	141	0.19	70500000	0.006552
1.8	159	1.59	159	0.21	79500000	0.007241
2	177	1.77	177	0.23	88500000	0.007931
2.2	195.1	1.951	195.1	0.249	97550000	0.008586
2.4	213	2.13	213	0.27	1.07E+08	0.00931
2.6	230.5	2.305	230.5	0.295	1.15E+08	0.010172
2.8	245.5	2.455	245.5	0.345	1.23E+08	0.011897
3	256	2.56	256	0.44	1.28E+08	0.015172
3.2	269.5	2.695	269.5	0.505	1.35E+08	0.017414
3.4	276.5	2.765	276.5	0.635	1.38E+08	0.021897
3.6	287	2.87	287	0.73	1.44E+08	0.025172
3.8	296.5	2.965	296.5	0.835	1.48E+08	0.028793
4	300.5	3.005	300.5	0.995	1.5E+08	0.03431
4.2	312	3.12	312	1.08	1.56E+08	0.037241
4.4	312.5	3.125	312.5	1.275	1.56E+08	0.043966
4.6	319	3.19	319	1.41	1.6E+08	0.048621
4.8	315.5	3.155	315.5	1.645	1.58E+08	0.056724
5	317	3.17	317	1.83	1.59E+08	0.063103

Table 2, Measurements of the aluminium specimen.

Width	Thickness	Length
2mm	1mm	29mm

Table 3, Figures calculated using previous data.

Tensile Strength (N/m ²)	Yield Stress (N/m ²)	% Elongation	Youngs modulus
1.60*10 ⁸	5.2*10 ⁷	6.310344828	1E+10

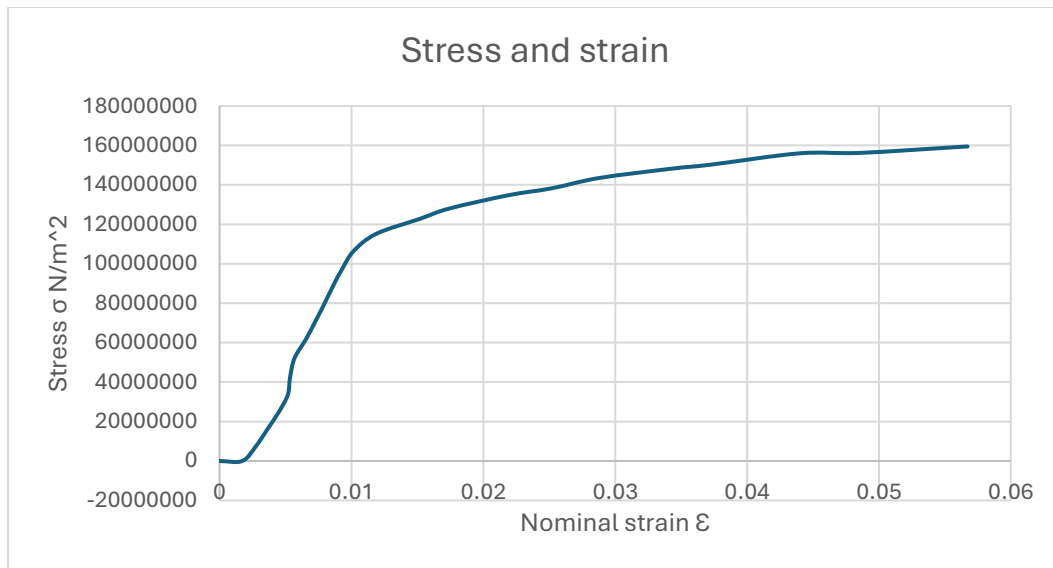


Figure 3, A stress and strain graph.

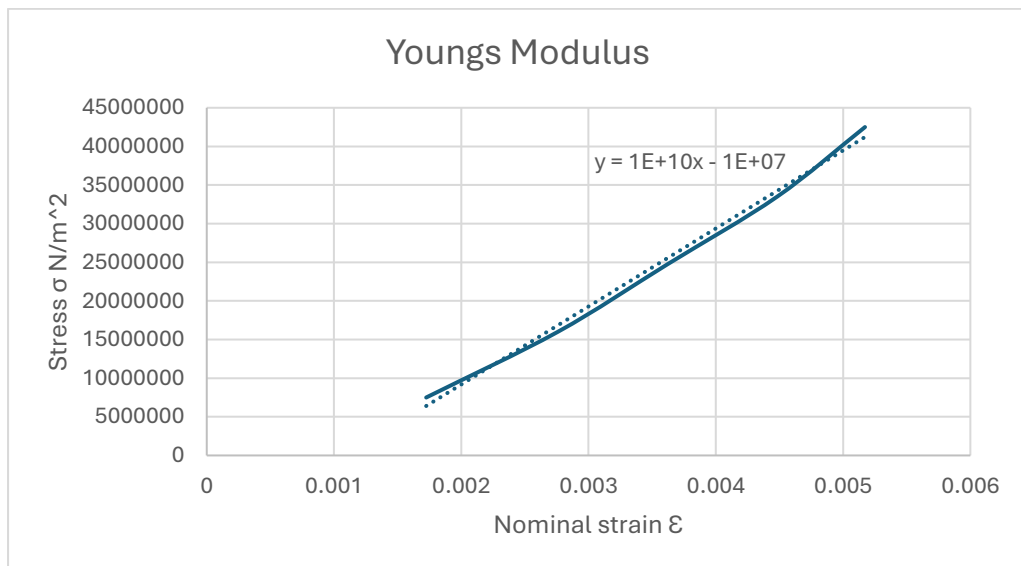


Figure 4, Stress and strain graph used to calculate the Youngs modulus.

5. Analysis

The data collected from this test seems to suggest that the aluminium used in the test was much weaker than that of what is usually used in drive shafts, 6061-T6 for example has a Young's modulus of 68.9 GPa whereas the value for the test specimen was merely 10 GPa. This is a clear cause for the failure of the drive shafts applied in the Dakar cars. This theory is suggested by the tensile strength, what should be 290-338 MPa was actually 160 MPa. This suggests that either the wrong temper was used, the wrong alloy was used or the material had defects.

The expected stress on a driveshaft in the Dakar rally is around 90 MPa, while this does mean that the strength of our aluminium drive shaft should be sufficient. But the expected cause is the wear cycles caused by the rough and repetitive nature of the type of race.

The stress strain graph (figure 3) produced by the data seems to be in line with how aluminium is expected to react, featuring a curved yield point.

6. Conclusion

In conclusion the failure was likely caused by the wrong alloy being used by the new provider, as from the multiple specimens such as the test piece and the two drive shafts all failed to provide anywhere close to the adequate level of strength needed. To prevent this in the future a new provider could be sourced who could be reliable. If this is deemed not to be possible, when new drive shafts are provided by the supplier the material should be tested prior to installation on the cars to ensure quality.

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