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Engineering Materials

Materials and Manufacturing (ACHA4025)

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04/2026

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1. Introduction

The Dakar Rally is often labelled as one of the toughest events in motorsport. Beginning in 1978 and inaugurated as the 'Paris-Dakar rally', the event began in Paris, France and ended in Dakar, Senegal (Chen, 2023). The event has since relocated multiple times, and as of 2026 takes place in Saudi Arabia (Dakar, 2026). The rally is known for its difficult terrain, often responsible for pushing vehicles to and past their limits.

The purpose of this report is to perform a tensile test on a material sample provided by a material manufacturer that produces driveshafts. These driveshafts have been used by a team in the Dakar rally, and failed on both vehicles during the later stages of the rally. The aim of the test is to investigate the cause of the failure, and analyse the material. The test will determine its young's modulus, yield strength and ultimate tensile strength. The report will also present ways to mitigate similar failures in the future.



Figure 1 - Audi RS Q e-tron competing in the Dakar rally (Audi Motorsport, 2026).

2. Literature review

There are many material properties that need to be carefully considered before an appropriate material is chosen for a driveshaft in any vehicle. This is even more important in a vehicle competing in the Dakar Rally. Different material properties have ways of being tested, using samples provided by material manufacturers. That said, certain properties are not as important in this application as others.

For a driveshaft used in the Dakar Rally, some important properties are:

Shear strength – the maximum stress a material is able to withstand when subjected to forces that cause sliding along a plane.

Fatigue strength – the ability of a material to withstand repeated load cycles without failing.

Torsional stiffness – the amount of resistance a shaft or beam has to twisting under high loads of torque.

According to the assignment brief, the new driveshafts have been manufactured identically to the previous driveshafts used by the race team. The maximum stress measured on the driveshaft during operation was 90 MPa, and a sample was provided to test the Shear strength of the material. The grade of the sample is unknown, but the material is known to be an aluminium alloy.

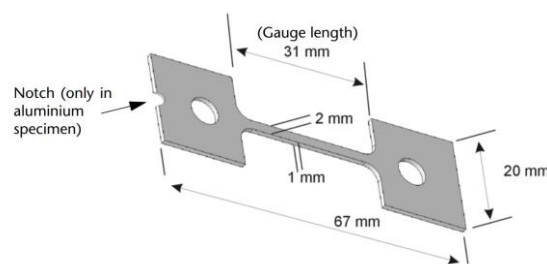


Figure 2 - Aluminium Specimen diagram (TecQuipment, 2012)

It is important to perform different tests on the material to ensure that it will be fit for purpose.

Tensile testing, which is explored in the methodology section of this report, is a process used to establish the operational load limits of metals and alloys. A material sample is set up in an apparatus so that a force can be applied and measured along one axis. Generally, the sample has a reduced width section intentionally to experience the highest stress (Ramesh Singh, 2020). This test provides the required data to determine the yield strength, ultimate tensile strength, and young's modulus, or modulus of elasticity.

Torsional stiffness testing should be carried out on the material to ensure that the driveshaft can withstand the high amounts of torque the drivetrain produces. Torsional stiffness is measured by applying a controlled amount of torque and measuring the resulting angle of twist (Ramlal, Desai and Dieng, 2026).

Fatigue testing is an important test to determine the fatigue strength of a material. Fatigue testing involves repeated loading and unloading of forces onto a material to determine its endurance limit (Gedney, 2025). The results for this method of testing are typically presented using a Wöhler curve, which plots the number of cycles until failure to stress amplitude.

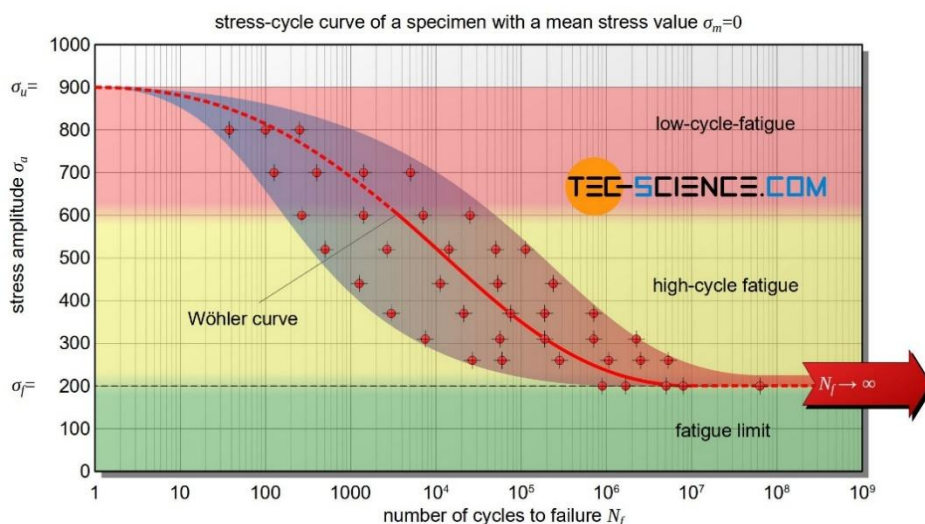


Figure 3 - Wöhler curve (tec-science, 2018)

Hardness testing is important for a driveshaft that will be used in the Dakar rally, due to debris such as rocks that may hit the driveshaft. Debris may fracture or dent the driveshaft acting as catalyst for fatigue fractures. A way of testing a materials hardness is the Brinell hardness test. This test consists of pressing a hard spherical indenter into the surface of the material under a constant pre determined load, and measuring the diameter of the indentation (Sundararajan and Roy, 2001).

3. Methodology

This experiment was conducted as per the guidelines set out in the Engineering Science Guidance Notes Tensile Tester Kit ES6 (TecQuipment Ltd, 2012).

Prior to testing, the apparatus must be set up. To begin, the large work panel must be screwed into the two supports with the provided thumbscrews. This will act as a base to mount the tensile testing apparatus, which is subsequently mounted to the work panel such that the dial indicator is towards the bottom and the load nut is at the top. It is important to note that it must be mounted in such a way that the load nut is above the top of the work panel and can therefore spin freely. Measure and record the original length of the specimen.

Next, the two nuts on the top and bottom chuck must be undone using the provided Allen key, and the provided specimen screwed into the top chuck. Then using the load nut, the top chuck is raised or lowered so that the specimen lines up with the bottom chuck and can be screwed in securely.



Figure 4 - Complete apparatus

Once the setup is complete, the test can begin. The load nut should then be turned until the dial indicator starts to move, at which point the load nut should be put to the nearest mark on the load nut scale. This scale is found on top of the apparatus. Once this is complete, the dial indicator should be turned until the needle points directly to the zero marking. The load nut scale consists of 10 evenly spaced markings, each one accounting for 0.1mm of stretch on the specimen, therefore one full rotation is equal to a millimetre of movement.

To record the data, the load nut must be turned two marks at a time (0.2mm), and the number on the dial indicator recorded. It is important to note that each reading on the dial indicator is equal to 0.01mm, and therefore 15 on the dial indicator is equal to 0.15mm. Once recorded, the number on the dial indicator is recorded at every 0.2mm increment until failure. Place the two parts of specimen back together and re-measure the final length.

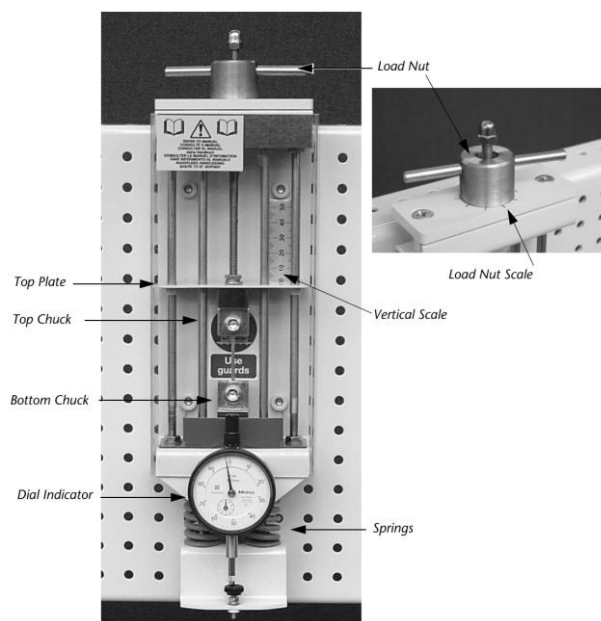


Figure 5 - diagram of tensile testing apparatus (TecQuipment, 2012).

4. Test Results

Load Nut Movement (mm)	Dial indicator (mm)	Force (N)	Extension (mm)	Stress (N/mm ²)	Nominal Strain
0	0	0	0	0	0
0.2	0.15	15	0.05	7.5	0.001608
0.4	0.32	32	0.08	16	0.002572
0.6	0.49	49	0.11	24.5	0.003537
0.8	0.68	68	0.12	34	0.003859
1	0.87	87	0.13	43.5	0.00418
1.2	1.05	105	0.15	52.5	0.004823
1.4	1.23	123	0.17	61.5	0.005466
1.6	1.39	139	0.21	69.5	0.006752
1.8	1.59	159	0.21	79.5	0.006752
2	1.76	176	0.24	88	0.007717
2.2	1.93	193	0.27	96.5	0.008682
2.4	2.1	210	0.3	105	0.009646
2.6	2.27	227	0.33	113.5	0.010611
2.8	2.39	239	0.41	119.5	0.013183
3	2.57	257	0.43	128.5	0.013826
3.2	2.6	260	0.6	130	0.019293
3.4	2.7	270	0.7	135	0.022508
3.6	2.79	279	0.81	139.5	0.026045
3.8	2.86	286	0.94	143	0.030225
4	2.91	291	1.09	145.5	0.035048
4.2	2.98	298	1.22	149	0.039228
4.4	3.01	301	1.39	150.5	0.044695
4.6	2.98	298	1.62	149	0.05209
4.8	fail				
5					

original length (mm)	final length (mm)
31.1	32.72

Table 1 - Raw data collected from the tensile testing experiment.

Young's Modulus	Yield Strength	Ultimate Tensile Strength
10.2 GPa	110 MPa	150 MPa

Table 2 - Measured results of notable features from tensile testing.

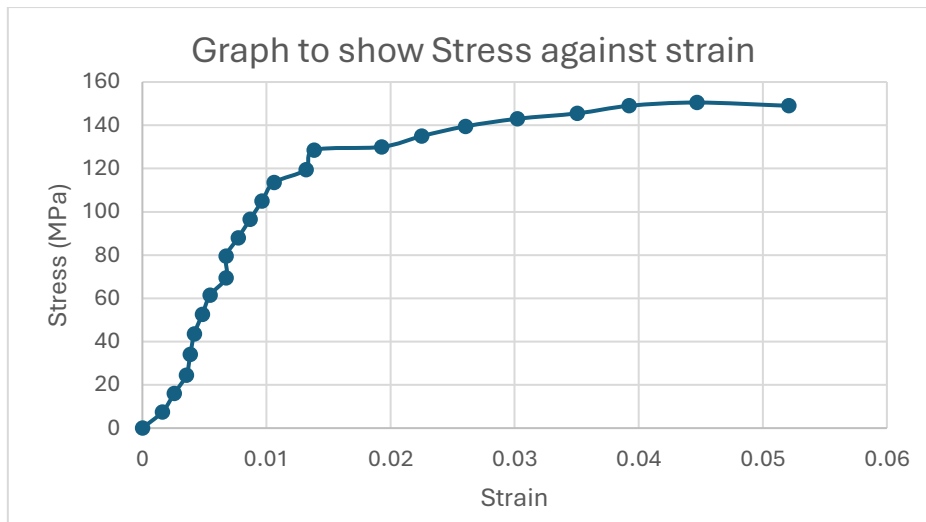


Figure 6 - Graph to show stress against strain using the aluminium sample provided.

As the data in table 1 and figure 6 shows, the aluminium sample starts to reach its yield point at around 110 MPa of stress, and 0.01 units of strain – this is the maximum amount of force the material can handle before it starts to deform. From this point it enters the plastic region and permanently deforms until it snaps at 150 MPa of stress, and 0.052 units of strain.



Figure 7 – Aluminium sample post testing after experiencing failure.

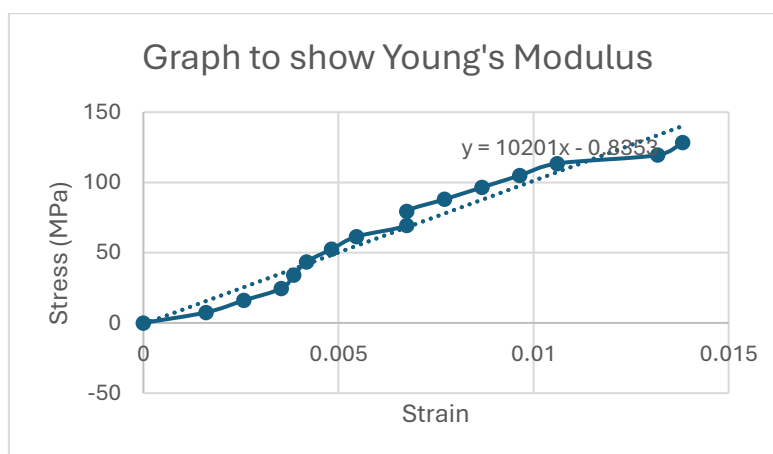


Figure 8 - Graph to show Young's Modulus on the aluminium sample.

5. Analysis

The data shows that the specimen failed at 150 MPa – 66.67% higher than the maximum force of 90 MPa that the driveshaft experienced during the Dakar rally. This indicates that the aluminium sample did not fail due to the material not having enough shear strength. Therefore, the ultimate tensile strength is 150 MPa.

[Young's Modulus:] $\text{Gradient} = E = \sigma/\epsilon$

As seen in figure 6, the Young's modulus is indicated by the gradient of the elastic region, which in this case is 10,201 MPa or 10.2 GPa. According to the research by AZO Materials (2019) Aluminium should have a value for Young's Modulus of 68 – 88.5 GPa. This indicates a serious flaw in the production of this aluminium alloy. While the report does not specify how the aluminium alloy is produced, a common way to manufacture these alloys is through casting. According to Fiorese et al. (2015), casting aluminium alloys is a “defects generating process”.

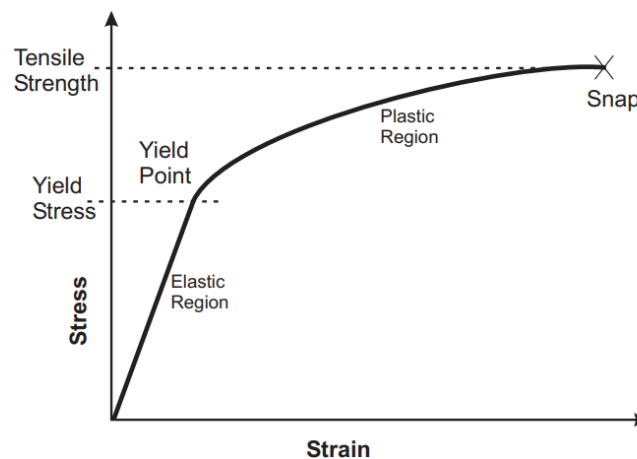


Figure 9 - typical stress/strain graph for an aluminium alloy (TecQuipment, 2012).

6. Conclusion

Looking at figure 10, there are clear signs that the failure of the driveshaft was due to fatigue. Though difficult to see in the image, there are striations on the smooth section. Striations are finely spaced lines present in fatigue fractures, oriented perpendicular to the origin of the fatigue crack (Kannadi Palankeeze Balan, 2018). Each striation represents a loading and unloading cycle after the fatigue crack formed, until the driveshaft could not sustain the applied load, and snapped harshly, resulting in the rough texture towards the lower half of the image. The quality of the image similarly makes it difficult to determine the exact site of where the failure initially occurred.

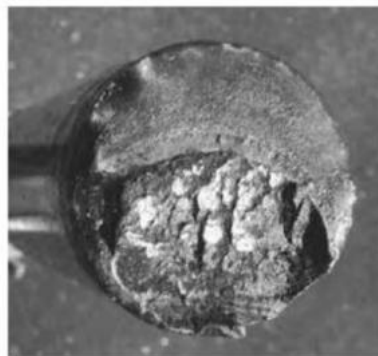


Figure 10 - failed section of driveshaft (Rogers, 2026).

To ensure that this failure does not occur again, the driveshaft should be altered in a few ways. Increasing the diameter of any fillets in the design reduces the likelihood of stress concentrators, as well as increasing the grade of aluminium used, or substituting it for a higher strength material. Since this problem has occurred since switching suppliers for the material of the driveshaft, the design team could return to the original supplier if possible.

If it is not possible to change the design or material, a fatigue test should be carried out on a sample of the material to determine the life cycle of the material. This would enable the team to replace the driveshaft before it reaches its endurance limit, reducing the chance of a failure while the vehicle is operating.

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