MATRIX | MATERIALS

ROTATING FATIGUE MACHINE

CP6995

Inspiring The Next Generation Of Engineers

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Laboratory Technique

Safety in the Laboratory

The principle hazards that arise from the use of mechanical experimental apparatus are where rotary or linear motion occurs and where the handling of loose heavy items, for example weights, is part of the procedure.

Should one of the heavier weights fall onto the feet of those around the apparatus there is a risk of injury. Hence it is recommended that weights be handled carefully and when moving and placing the heavier ones on load hangers should be regarded as a two handed operation. It is surprisingly easy to spill a complete stack of weights off a hanger when adding a further one.

In addition to weights there are some heavy parts that have to be interchanged during some experiments and a similar approach using two hands where required is suggested. It may also be both sensible and necessary for two people to take part in changes to the apparatus.

Success in the Laboratory

Work in the laboratory depends on understanding, observation and skill. In the first place a good understanding of the performance, and limitations, of experimental models is needed. To know about the theory involved is useful but not essential. In the second place keen observation leads to better results and avoidance of mechanical mistakes. Lastly, the way in which students Fixing Handle the apparatus can influence the accuracy and speed of the work.

To help students gain experience and improve their experimental technique a range of information is offered in the following notes. Bear in mind that in the world of real engineering it is often necessary to check the performance of new designs using the methods and instruments of laboratory experiments.

Design of Experimental Models

The purpose of each experiment is to illustrate an item of structural theory, or to show how well simplifying assumptions in the applied mathematics correspond to actual behaviour. This often requires the model to exaggerate the behaviour of a real structure.

In order to achieve specific objectives each experiment has a particular arrangement best suited to the theoretical requirement. These arrangements of the apparatus are described in the Construction Appendix, where included, of each experimental Instruction Manual. Before starting an experiment students should read through the Instruction Manual and be prepared to follow the recommended procedure.

Laboratory Technique

Increased deflections are usually achieved by using very flexible models. The stiffness depends on EI or EA so a change of material from steel (E = 205 kN/mm2) to aluminium (E about 1/3 E for steel) or a plastic (E about 1/80 E for steel) is a solution. The alternative is to use thin steel beams with a low I.

One disadvantage experimentally is that friction in bearings may affect displacements and force measurements. The other is that large changes in dimension (geometry) of models must be accommodated if possible.

Results can be improved by using stiffer models and larger loads, but this reduces visual effects such as curvature of beams.

Sources of Resistance

A knife-edge can simulate a frictionless pin or bearing, but horizontal and rotational movements demand ball bearings. These are packed with grease and fitted with shields to keep out dust and grit. Hence ball bearings have some torsional restraint, which affects forces in the order of magnitude 1 N. This shows up as a difference in readings for loading and unloading.

Pin joints in trusses are also subject to friction, which increases in proportion to the loading.

Repeatability of Readings

The ability to obtain accurate and repeatable experimental results is generally a matter of care and technique. Of course it helps to know the sources of error and to recognise when the apparatus contributes to the variability of readings.

Frictional variation can be minimised by using vibration. The extent of the friction can be observed by first increasing and then decreasing an applied load by hand to get the difference in readings. Tapping the frame on which the experiment is mounted will reduce the variation.

Cast iron weights for loading must always be applied gently. A load suddenly added will instantaneously apply twice its static value. Although weights are hand finished there is a manufacturing tolerance of ± ½%. This may affect linearity in experimental readings.

Safety Information

Electrical

The colour coding of the cable is as follows:

110 V~	LINE	BROWN
	NEUTRAL	BLUE
	EARTH	GREEN/YELLOW
230 V~	LINE	BROWN
	NEUTRAL	BLUE
	EARTH	GREEN/YELLOW

It is essential that the equipment be connected to a properly earthed mains supply. Failure to observe this notice could result is serious injury.

The unit operates at 230V. A transformer is supplied to accommodate lower mains voltages such as 115V. This unit is runs between 50 Hz and 60 Hz.

The fuse rating is 1.6A anti surge. Under no circumstances should alternative ratings be substituted!

The (continuous) current consumption of this equipment is 1 A at 230 V~.

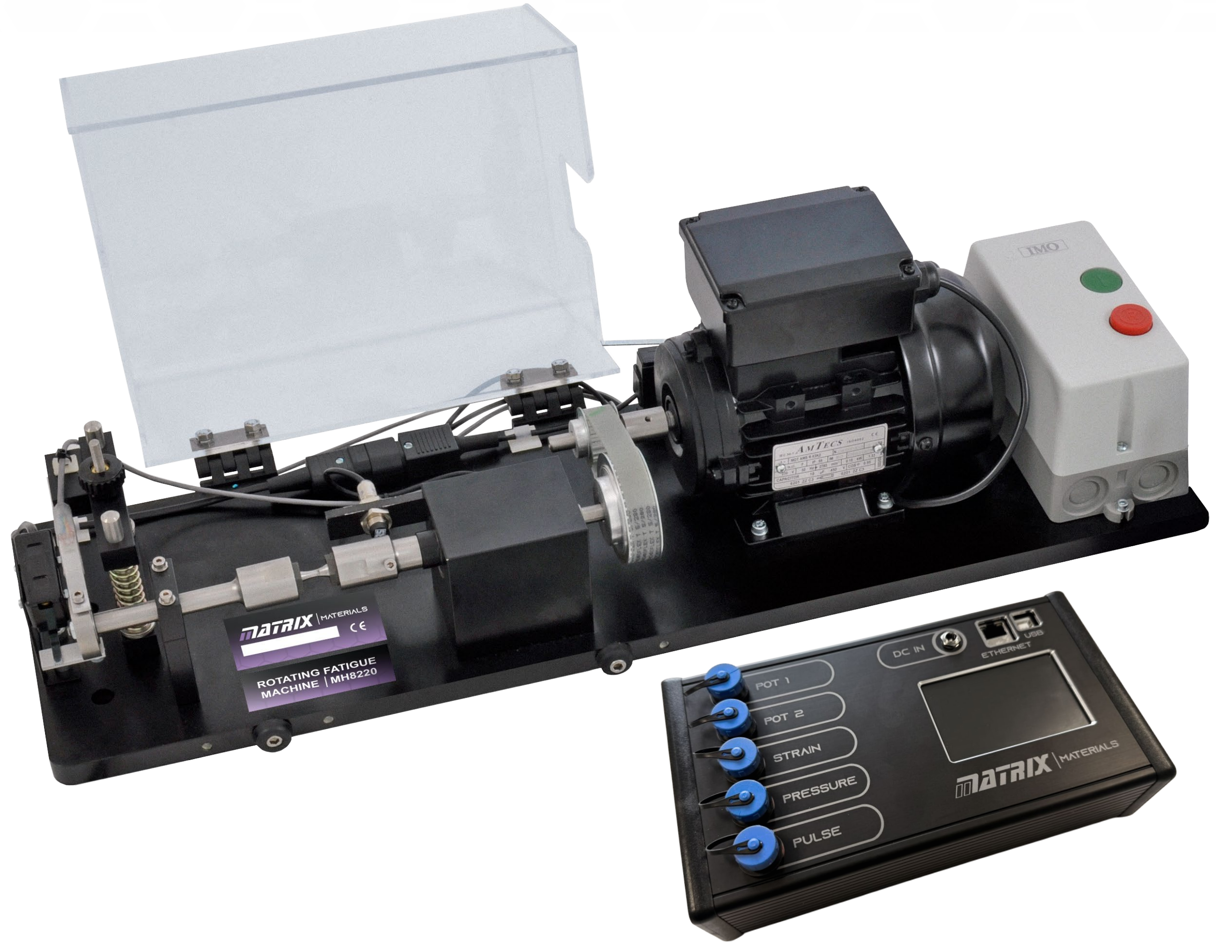
An inline RCD is fitted along with IEC sockets.

Operation

The unit is designed for us in a teaching laboratory with appropriate guidance and supervision; it is essential that the experimental guidelines within this document be studied before using the apparatus.

This equipment is fitted with a safety guard – it should not be removed, except by qualified maintenance personnel. NEVER operate this equipment without the guard fitted.

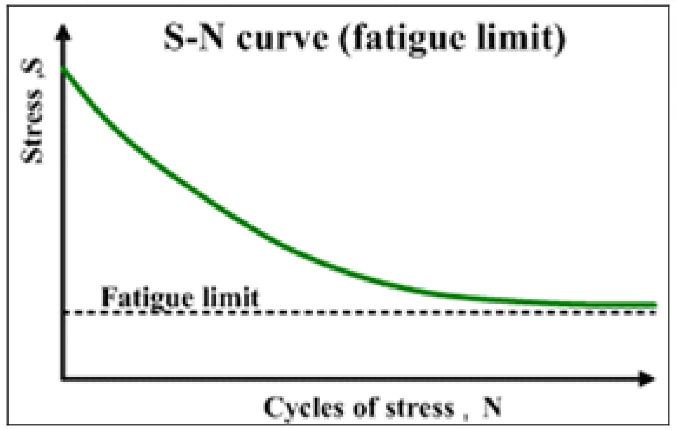
Introduction



Fatigue of materials is a well-known situation whereby rupture can be caused by a large number of stress variations at a point even though the maximum stress is less than the proof or yield stress. The fracture is initiated by tensile stress at a macro or microscopic flaw. Once started the edge of the crack acts as a stress raiser and thus assists in propagation of the crack until the reduced section can no longer carry the imposed load. While it appears that fatigue failure may occur in all materials, there are marked differences in the incidence of fatigue. For example, mild steel is known to have an 'endurance limit stress' below which fatigue fracture does not occur: with aluminium alloys, however, there is no such limit.

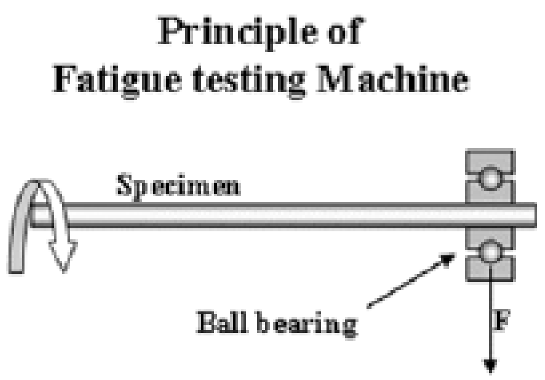
As a consequence of these differences there are two design methods. With a material like mild steel the actual stress range can be kept below the endurance limit. Alternatively one can design for a specified number of stress variations, on condition that the part will be replaced at that stage. The latter method is quite common with aircraft where the use of aluminium is widespread.

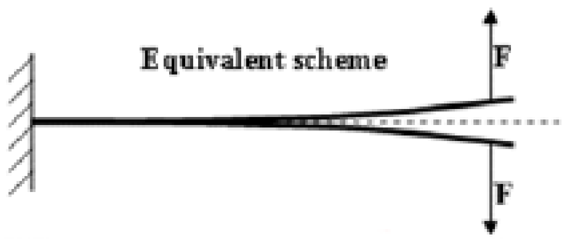
Introduction



If design is to be based on a possibility of fatigue failure then test data must be produced to this end. The subject of fatigue testing is extensive, and is complicated by important factors like the surface condition of the specimen, the type of stress variation, and the influence of the shape of the specimen on the stress flow. It is known that highly polished specimens withstand fatigue better than normally machined ones. The most damaging type of stress variation is the complete reversal, that is between the limits $\pm \sigma$ for which the stress range is 2σ. Fluctuating stresses are less damaging, the standard case being between the limits of 0 and $+ \sigma$. The shape of a machine part is very important, since it is known that at corners and notches the local stress can be several times more than the calculated average value. Evidently since fatigue is a localised stress phenomenon any form of stress raiser must affect performance.

To introduce this very complex subject in a simple way, the apparatus demonstrates the classical fatigue experiments carried out by Wohler. He selected the method of reversing the stress on a part by employing a cantilever rotated about its longitudinal axis.





Hence the stress at any point on the surface of the cantilever varies sinusoidally. In the machine used here the cantilever is specially designed to use a relatively simple specimen with a definite minimum cross section.

APPARATUS DESCRIPTION

Apparatus Overview

Overview

At one end of a sturdy base plate is mounted an electric motor and starter box. The starter box ensures safe starting of the motor. The motor shaft carries a pulley with a belt drive to a counter shaft so that different ratios of speed can be arranged.

The counter shaft, running in a substantial bearing block, has a collet chuck of 9 mm ID (internal diameter) to carry a rotating cantilever. A data acquisition box is attached to the force sensor and counter sensor via connectors that are run through a hole in the base. This box contains a resettable counter and force reading which displays the applied force to the test specimen. There is a USB socket on the front of the box which allows the connection of the apparatus to a PC (not supplied) from which the experimental software can be run.

The data acquisition box is powered using a separate power supply transformer, this also powers the sensors for the unit.

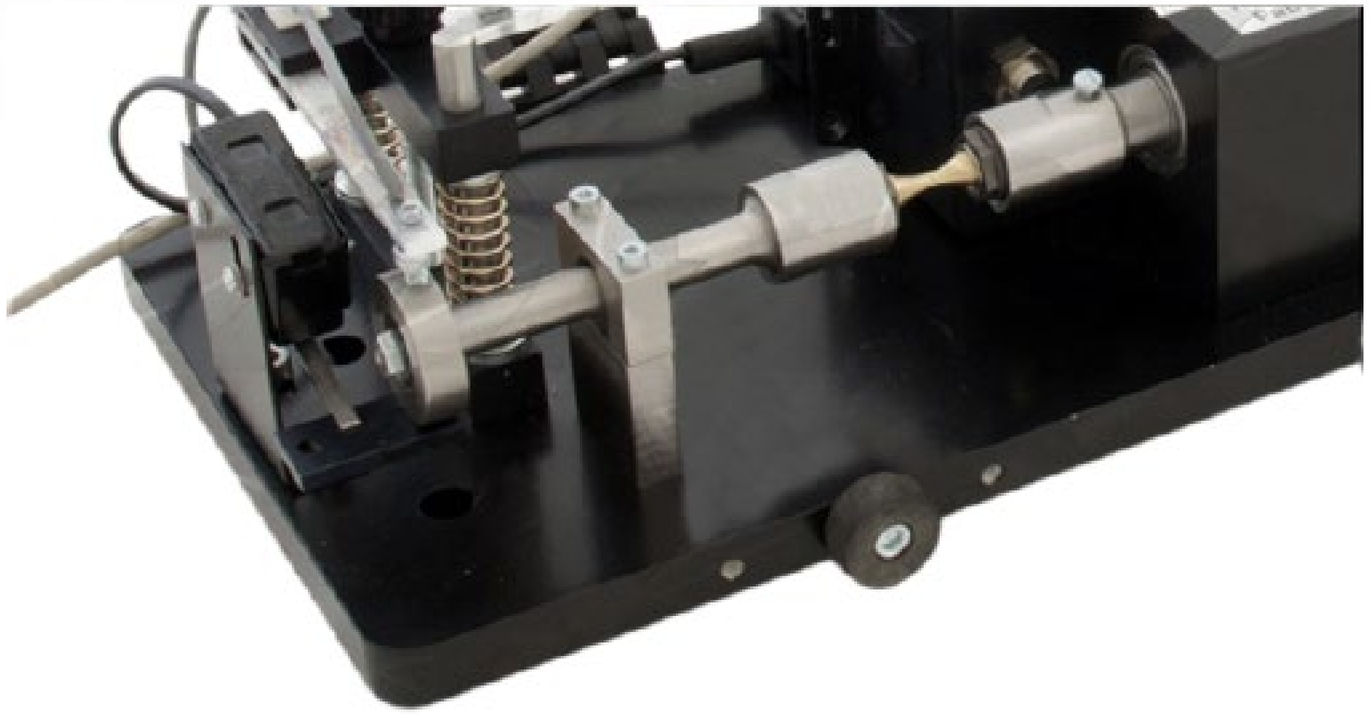
Differing material specimens can be attached between the counter shaft and cantilever. Load is applied to the cantilever, and hence specimen, through a ball bearing at one end. The bearing ensures a static load can be applied to a dynamic specimen. A screw jack mechanism, with an integral load cell, forces the end of the cantilever downwards and hence applies a load to the specimen. The load cell output is fed into the data acquisition box, which then shows the force being applied (N).

A micro switch senses the downward deflection of the loaded end of the cantilever. As fracture occurs the switch cuts off the electrical supply to the motor. The number of revolutions to fracture is then displayed on the touch screen, if a force reading is set this should zero as the sample will have broken and no load will be applied.

The guard, which encloses the apparatus, bears on to a micro switch, which enables the motor to operate when power is available. If the guard is not 'hinged' down, then the motor will not start. To test or run the machine this guard must always be in place.

The profile of the specimens has been designed such that fracture will occur at the smallest diameter, i.e. at the centre of the specimen.

The data acquisition box has a USB connection to a host computer (not supplied). This enables the parameters of applied force, specimen revolutions and count to be captured and analysed at a later date. Software supplied allows this data to be captured and displayed on a computer screen as the test is being run.



Base Plate

Contains all the main parts of the rotating fatigue machine. It comes fitted with rubber mounting feet to ensure sturdy, balanced mounting and a minimal damping of rotational vibrations. The base plate is earthed to the mains.

Starter Box

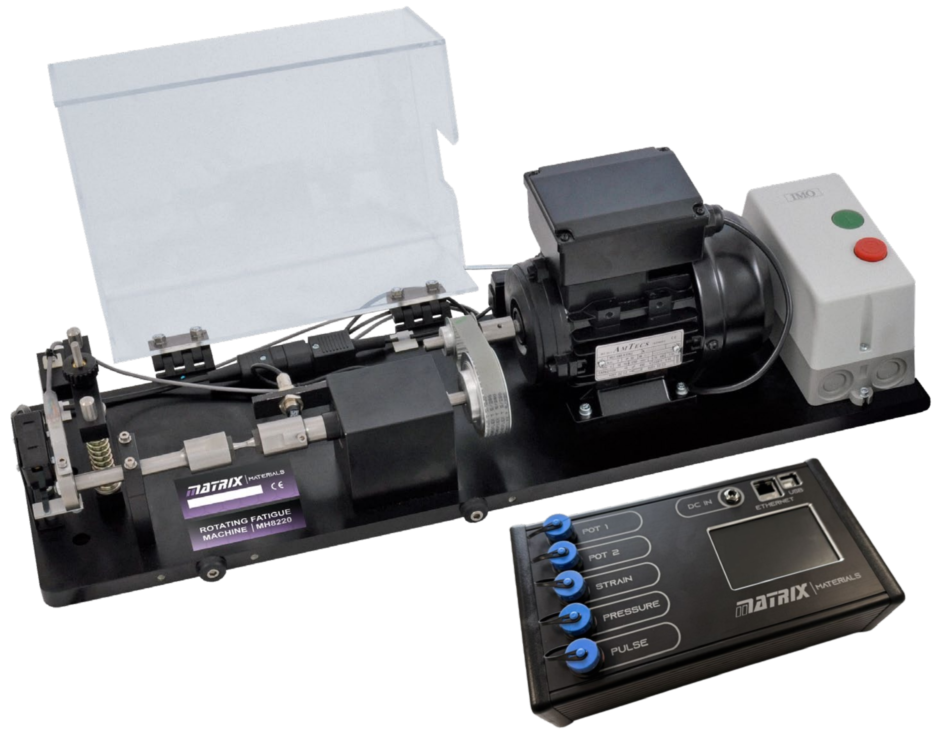
The starter box has a red and green button as shown above. The red button is to stop the motor. The green button is to start the motor.

When the specimen breaks the motor will shut off. To restart the motor, the red button will need to be pressed, followed by the green button.

Motor

The motor is a 230Vac, single phase motor, with a shaft speed of 2800rpm. It mounts to the base plate in 4 positions and can be adjusted laterally if the belt tension is required to be adjusted. Four screws and washers are used to tighten the motor into position.

Attached to the motor is a coupling shaft, which allows the small diameter motor shaft to be directly attached to one of the two pulleys supplied with the unit.

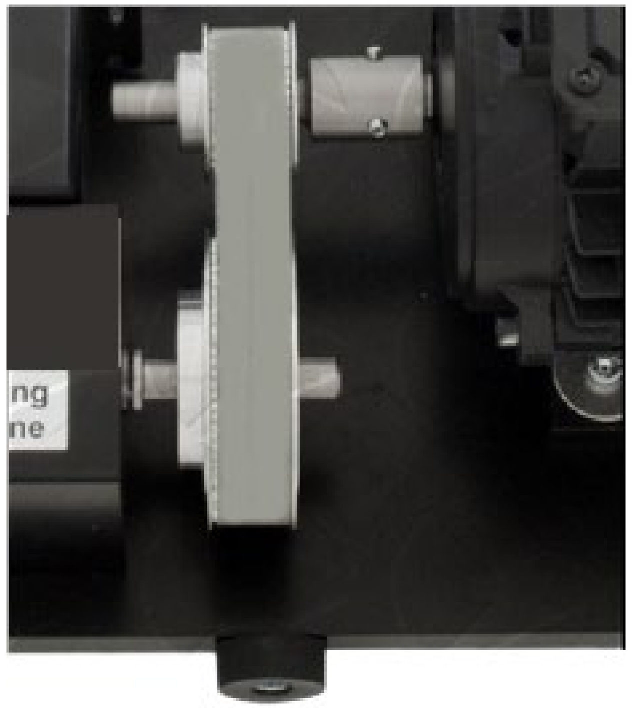


The motor will cut off if either of the micro-switches are released, this is done by either lifting the safety guard lid or when a sample is broken. The stop button on the starter box will also stop motor.

Before starting the motor check that the belt tension is correct and that the pulleys are fixed securely to their respective shafts.

Do not cover the motor whilst in use, ensure that all rotating parts are free from foreign objects including previous broken samples etc.

Pulleys and Belt



Two pulleys are supplied with the unit
1 x 20tooth
1 x 40tooth

One pulley mounts to the motor coupling, whilst the other pulley mounts to the counter shaft.

This ratio of pulleys, along with the motor speed, allows the specimen to be rotated at either 5600rpm or 1400rpm. The pulleys are joined using a timing belt, whose tension can be adjusted through the motor mounting adjustment.

The pulleys mount to their respective shafts by means of small socket set screws and can be swapped, depending on the speed of rotation required.

Bearing Block

The main bearing block attaches to the base plate using small hexagon set screws and washers. These fasteners run in slots in the base plate, thus providing another means of adjusting the belt tension.

The bearing housing has two large precision bearings mounting inside each face. These bearings house the main counter shaft, with the shaft retained inside the bearings by the use of external circlips. The counter sensor is held in place via a bracket which is fixed to the bearing block.

APPARATUS DESCRIPTION
Apparatus Description

Counter Shaft

The counter shaft has a pulley attached at one end and a collet chuck at the other.

The collet chuck sits inside the bore of the counter shaft. The bore of the collect chuck is Ø9mm. This suits the diameter of the Ø9mm test specimens, with allowance for inserting the specimen into the chuck.

The counter shaft has a screw fixed on its perimeter. This creates a ferrous object for running across the surface of the proximity sensor (which is held in place onto the bearing block). Each time the screw head passes over the sensor a signal is created which is fed back to the counter within the display unit. This signal is then used for counting the number of complete specimen cycles AND the rotational speed of the specimen (RPM).

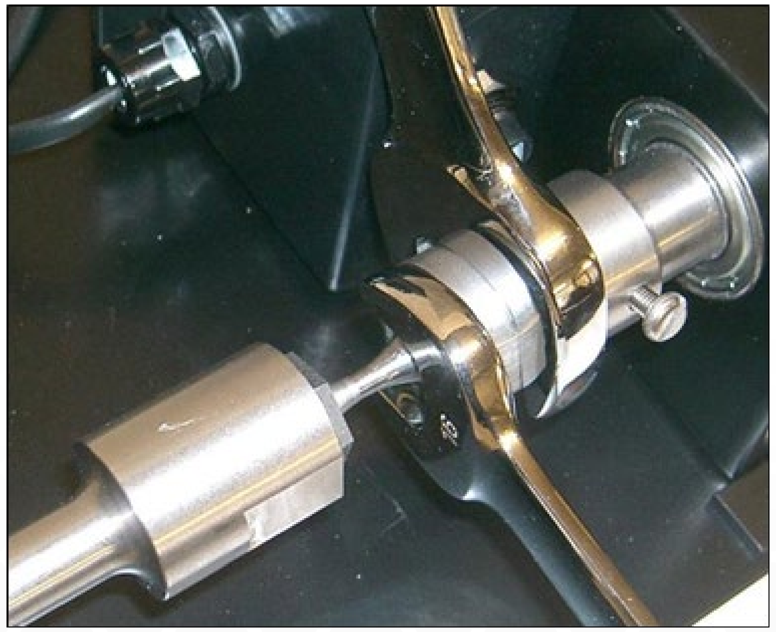
Collet Chucks

The collet chucks secure the test specimens in position. Each chuck has a Ø9mm bore to suit the specimen and a hexagonal nut at its front edge. This nut is used to tighten the collets around the specimen AND to grip the chuck to the inside surface of the counter shaft and cantilever shaft.

To tighten the collets around the specimens the following are supplied:

16mm A/F spanner
23mm A/F spanner

The 16mm spanner is used on the nut of the collect chuck. The 23mm spanner is used on the flats of the counter shaft and cantilever shafts, as shown



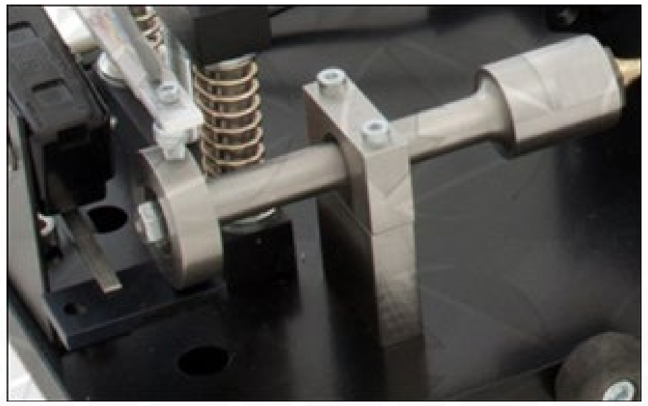
Prior to running the unit, ensure the collet chucks are tightened fully and the specimen will not rotate inside the chucks or come loose. The positioning and security of the specimen is crucial to obtaining fair and repeatable results.

Cantilever Shaft

The cantilever shaft secures the floating end of the test specimen. It again houses a collet chuck at one end. At the other end a bearing housing is attached using a nyloc nut and washer.

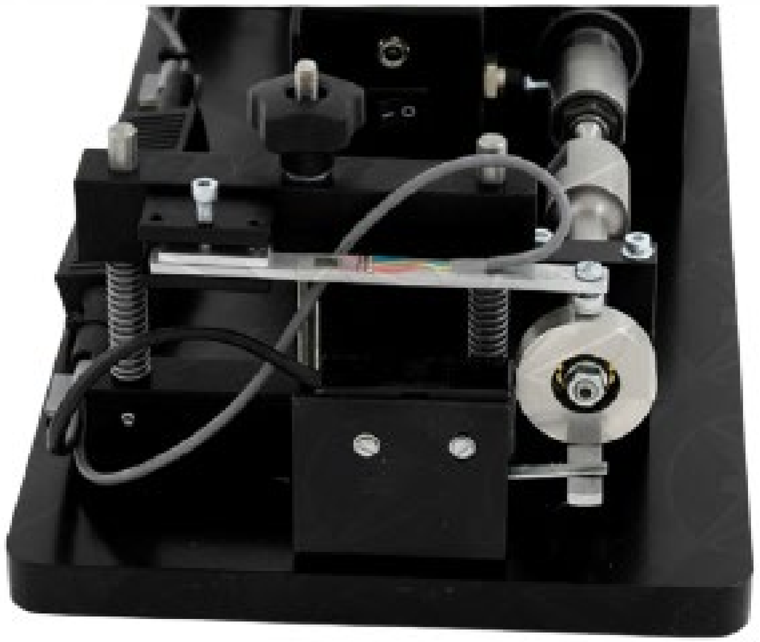
Support Block and Clamp

This part is used as a guide for the main cantilever shaft this helps for consistency of results as a bent or angled specimen will behave differently under loads. The clamp is also in place so that the parts are still secured when the sample is broken. The top part of the support block and clamp should not be removed, this will help to ensure that the cantilever shaft will not be lost from the unit.



APPARATUS DESCRIPTION
Apparatus Description

Bearing Housing



The bearing housing, containing a precision ball bearing, allows a static load to be applied to the end of the cantilever shaft, and hence specimen, whilst the specimen is rotating.

The load is applied to the bearing housing via a load cell and its screw. The screw sits inside a socket head set screw to allow for alignment as well as unrestricted downward movement when the specimen breaks.

Protruding from the bearing housing is a Microswitch arm. This allows the lever of the Microswitch to rest in a position such that when the specimen is un-fractured the Microswitch is not activated and the motor operates. When the specimen breaks the bearing housing and Microswitch arm drops vertically and hence the Microswitch arm drops and activates the Microswitch. This shuts down the motor but not the revolution counts. The Microswitch can be adjusted to fine tune the activation point by adjusting the plate onto which the Microswitch is mounted.

The specimen loading is applied using the screw jack mechanism located at the end of the base plate. It consists of a central screw jack, with integral thumb knob, damping springs, two ground rods and a load cell.

When the screw jack is rotated clockwise (when viewed down onto the thumb knob) the load cell will be raised away from the bearing housing on the end of the cantilever. When the screw jack is rotated anti-clockwise the load cell is lowered onto the bearing housing. This then allows fine adjustment of the applied load.

The load cell output is fed into the data acquisition box via the load cell wire.

The data acquisition box is connected to the sensor connectors which are fed through a hole in the base. The unit can be used and calibrated once a test has been setup. It has a touch screen display which allows the display of the number of revolutions (count) and the force (N) applied to the specimen. The count can be reset and the load can be tared using Zero and Tare buttons.

The power supply for this unit is a 24VDC. It is plugged into the socket labelled DC IN. The unit is supplied with interchangeable primary plugs. The supplied plug heads are for use with sockets styled for UK, Europe or America. Below is an image of the supplied parts

DATA ACQUISITION BOX
Data Acquisition Box

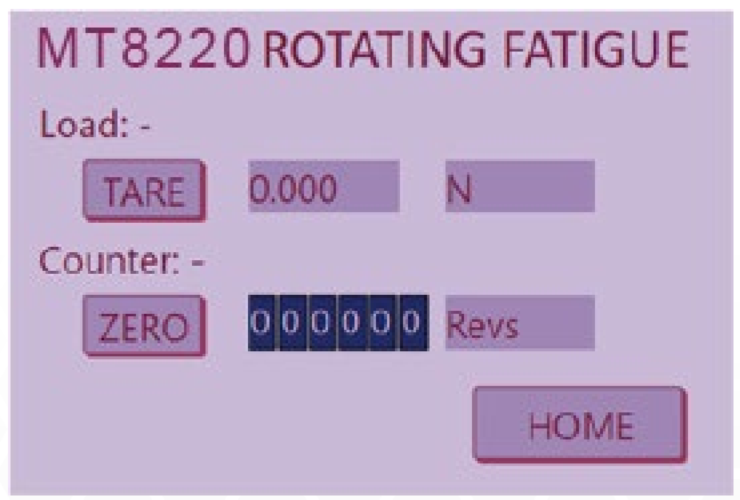
The Unit is supplied with the correct Jack Plug fitted. It is recommended that only the supplied power supply be used with the product. If any replacement is needed, please contact matrix.

The electrical details of the power supply are as follows:

Input: Between 80 and 264VAC at a frequency between 47 and 63 Hz.
Output 24VDC 60W

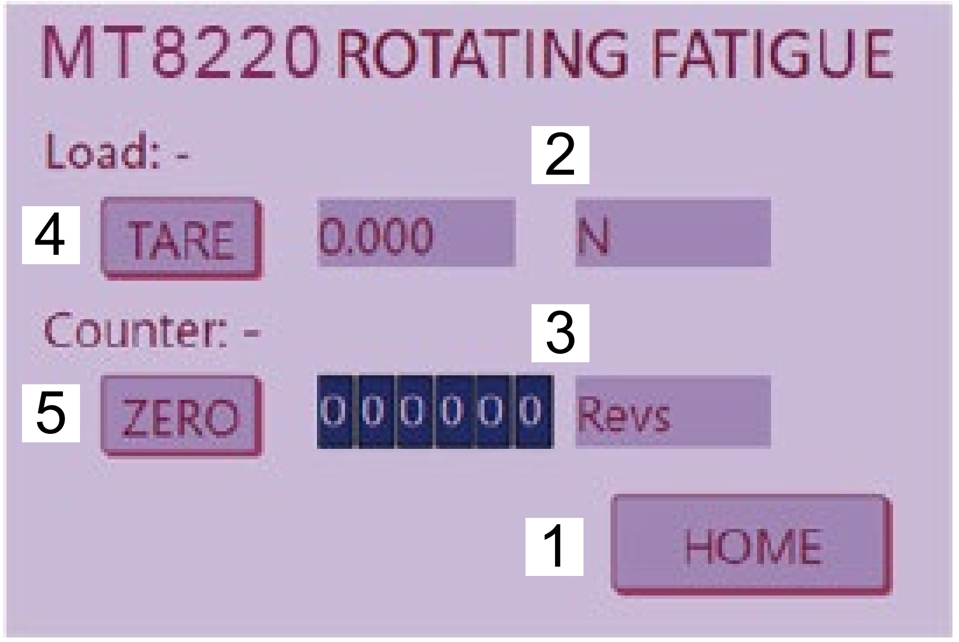
The load cell and proximity sensor have connectors attached at the end of their wires, these connect into the corresponding sockets in the front of the data acquisition box. The proximity sensor of the counter shaft is plugged into the socket labelled Pulse/Drive. The strain gauge of the loading mechanism is plugged into the socket labelled Strain.
A USB socket is can be connected between the box and a PC. This enables sensor and counter readings to be plotted and logged to a file.

When the unit is powered up. It will display the main menu. Touch the Fatigue button to show the screen for the rotating fatigue machine. Below is an image of the fatigue machine display. The elements of the screen are described below.



DATA ACQUISITION BOX

Data Acquisition Box



1: Home Button
Touching this button will cause the touch screen to return to the main menu.
2: Load Display
This shows the applied load and the units.
3: Counter Display
This shows the current revolution count.
4: Load Tare Button
This tares the load display. The display will read zero and all subsequent readings will be relative to the current output.
5: Counter Zero Button
This button zeros the counter so that it starts counting again from zero.

It is important to set the count to zero before commencing with any testing, or at least record the number of counts prior to running a test.

When the specimen fractures the count will stop increasing and will remain on the screen.

The force displayed on the touch screen is the force applied to the specimen. The units for this display are Newton's (N) and the force reading increases as the load cell screw is tightened. It is advised to zero the force when the load cell assembly is free from the bearing housing before tightening the load cell screw and increasing the force that is applied to the test specimen.

DATA ACQUISITION BOX
Data Acquisition Box

Acrylic Safety Guard

The safety guard is hinged onto the base plate from the back. It can be hinged when needing to the run the test and then unhinged when replacing specimens, tare the counter box, etc.

With the guard hinged down the Microswitch behind the motor will be activated and the motor should operate. If the motor does not operate ensure the Microswitch is activated by moving the Microswitch lever up and down. It may be that the factory set position has moved in some way.

Figure 1: Guard Hinged Down

Figure 2: Guard Hinged up

A PC application is available that takes measurements from the Data Acquisition box, displays them on a chart and logs to a file. The software is designed to be as flexible and possible, with many parameters that are editable to increase the amount of experimental options as much as possible.

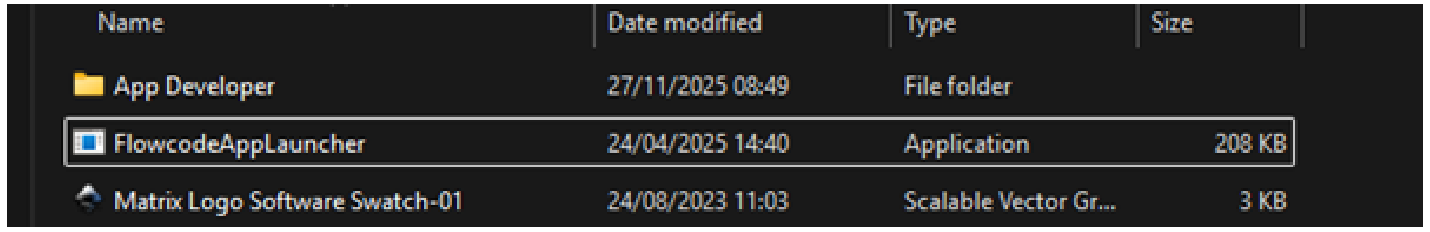
Installation
The software can be downloaded from the Matrix website. Choose Materials from the Products menu. On the Materials page, select the Resources tab. The Data Acquisition software is available to download in a zip file.

www.matrixtsl.com/materials

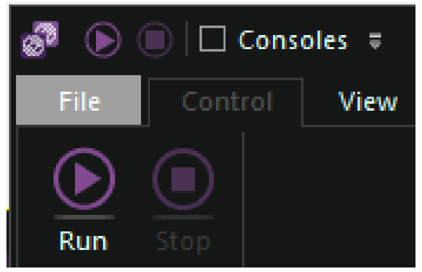
Save the zip file on a Windows PC and extract the whole folder in a convenient location.

Running the Software

To start the software, open the folder and run the file FlowcodeAppLauncher.exe.



Connect a USB cable between the Data Acquisition Box and the PC. Plug the 24VDC power supply into the socket labelled 'DC IN'. Wait for the device to power up and show the main menu, then click the Run button in the top left corner of the software screen. Alternatively, a larger Run button can be found by clicking on the Control menu.

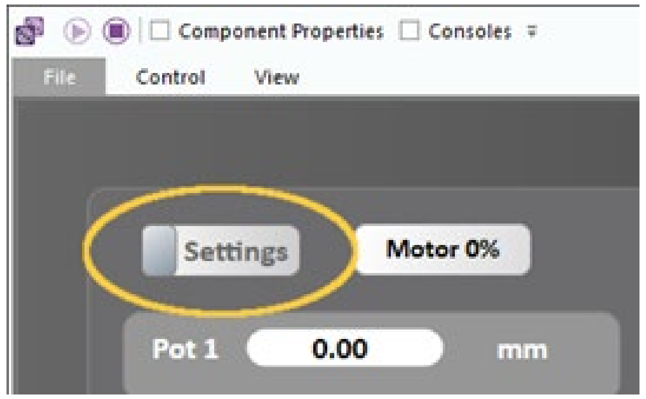


Run/Stop Buttons

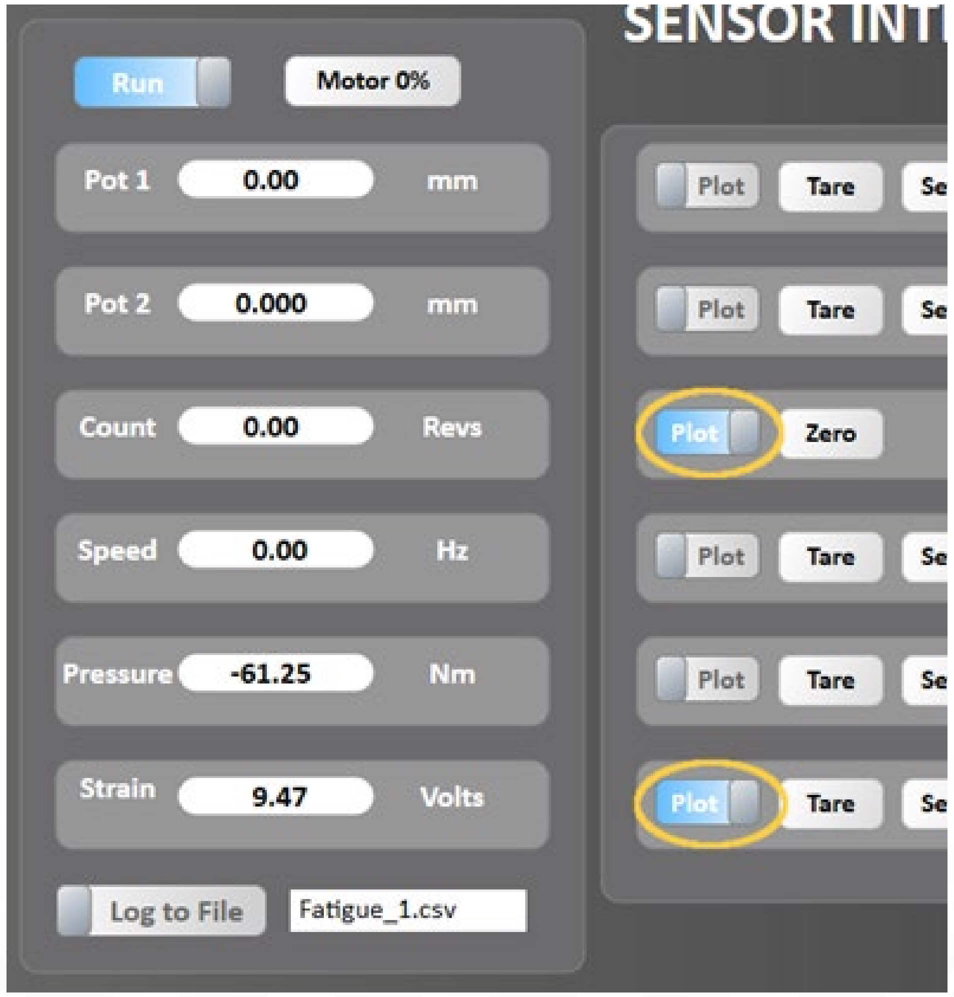
When the run button is clicked, the software should immediately begin displaying and plotting sensor values.

Capture and Plot Data

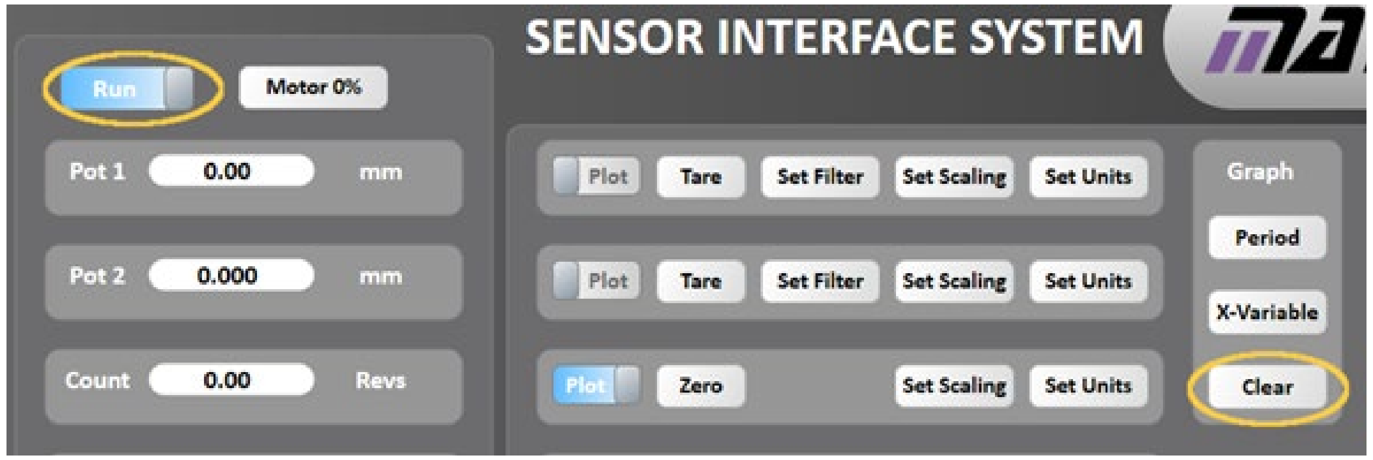
With the software running, click on the Settings mode switch to hide the graph display and enter settings mode.



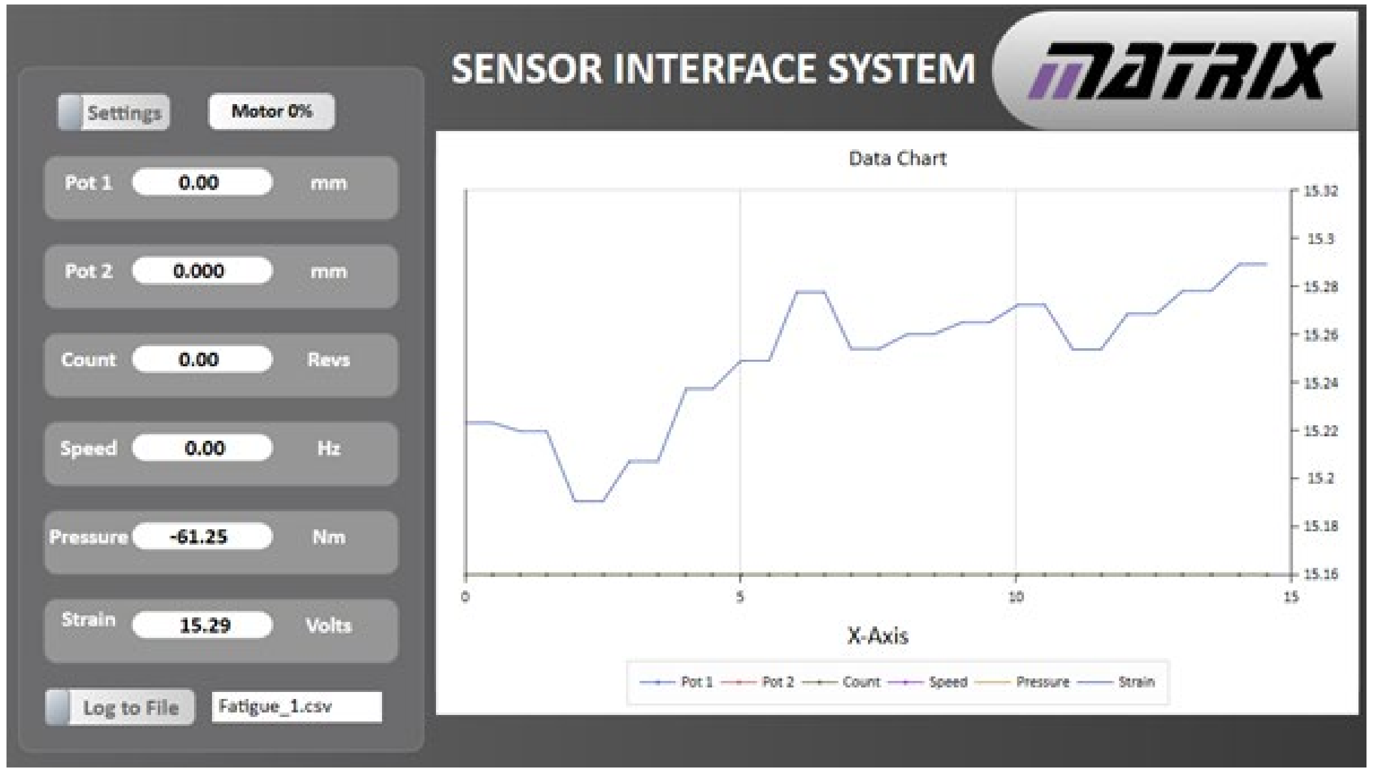
In settings mode, switch on plotting for the Counter and Strain channels. Switch off plotting for the remaining channels.



In settings mode, switch on plotting for the Counter and Strain channels. Switch off plotting for the remaining channels.



In live data mode, the measurement values will be plotted on the graph.



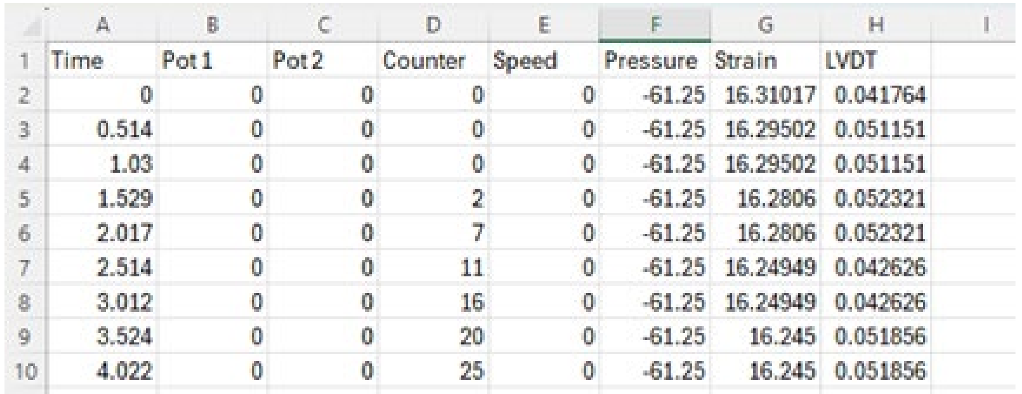
Log Data to File

To log the recorded data to a file, type a file name into the box at the bottom left of the window. Then, click on the Log to File switch. All received data will now be written into the specified file. The file will be stored in the same directory as the application.

Once a test is complete, click the log switch again to suspend writing to the file. The file is now available for importing into an analysis program.

Import Data into Spreadsheet

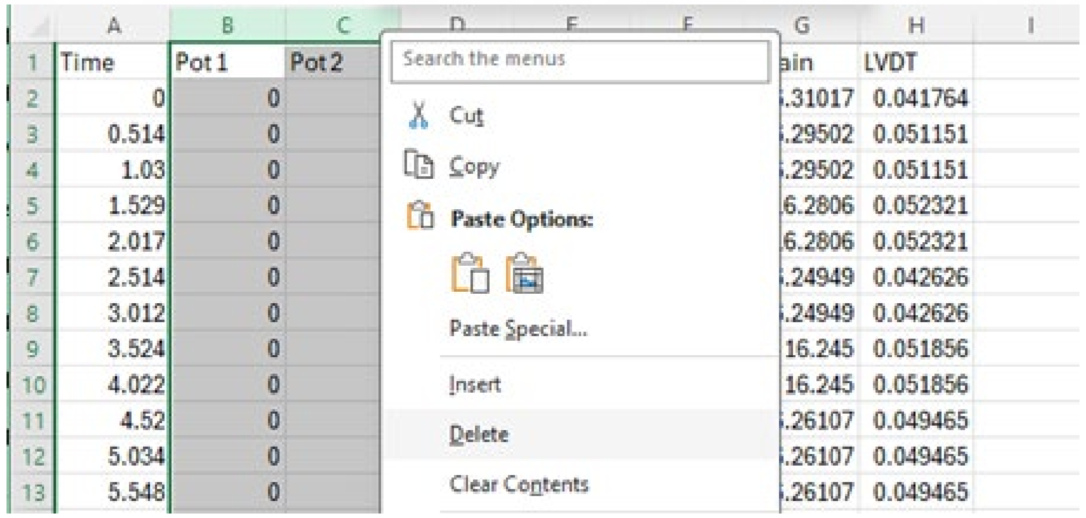
The logged file is saved as a comma-separated-value file. It can be opened in a text editor, a spreadsheet or many data analysis programs. The software will store all sensor channels regardless of whether they are plotting or contain valid data. The file begins with the column headings; Time, Pot 1, Pot 2, Counter, Speed, Pressure, Strain and LVDT.



	A	B	C	D	E	F	G	H	I
1	Time	Pot 1	Pot 2	Counter	Speed	Pressure	Strain	LVDT	
2	0	0	0	0	0	-61.25	16.31017	0.041764	
3	0.514	0	0	0	0	-61.25	16.29502	0.051151	
4	1.03	0	0	0	0	-61.25	16.29502	0.051151	
5	1.529	0	0	2	0	-61.25	16.2806	0.052321	
6	2.017	0	0	7	0	-61.25	16.2806	0.052321	
7	2.514	0	0	11	0	-61.25	16.24949	0.042626	
8	3.012	0	0	16	0	-61.25	16.24949	0.042626	
9	3.524	0	0	20	0	-61.25	16.245	0.051856	
10	4.022	0	0	25	0	-61.25	16.245	0.051856	

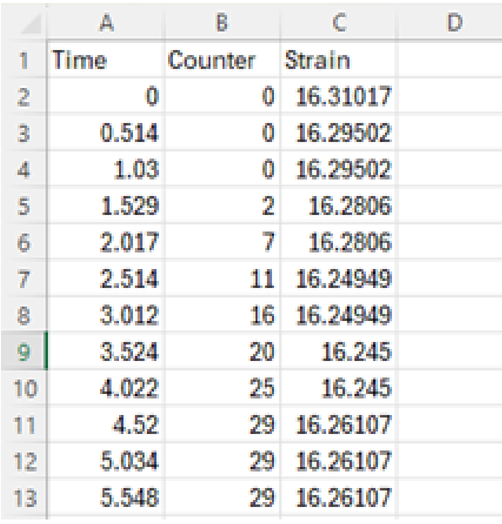
The useful columns in torsion tests are: -
Time – the time in seconds of the reading.
Pot 1 – The reading from the angle sensor.
Strain – The reading from the torque sensor.

In a spreadsheet application, the remaining columns can be selected and then deleted.



	A	B	C	G	H
1	Time	Pot 1	Pot 2	ain	LVDT
2	0	0		.31017	0.041764
3	0.514	0		.29502	0.051151
4	1.03	0		.29502	0.051151
5	1.529	0		6.2806	0.052321
6	2.017	0		6.2806	0.052321
7	2.514	0		.24949	0.042626
8	3.012	0		.24949	0.042626
9	3.524	0		16.245	0.051856
10	4.022	0		16.245	0.051856
11	4.52	0		.26107	0.049465
12	5.034	0		.26107	0.049465
13	5.548	0		.26107	0.049465

The relevant columns can then be used to analyse or plot the experimental data.



	A	B	C	D
1	Time	Counter	Strain	
2	0	0	16.31017	
3	0.514	0	16.29502	
4	1.03	0	16.29502	
5	1.529	2	16.2806	
6	2.017	7	16.2806	
7	2.514	11	16.24949	
8	3.012	16	16.24949	
9	3.524	20	16.245	
10	4.022	25	16.245	
11	4.52	29	16.26107	
12	5.034	29	16.26107	
13	5.548	29	16.26107	

Fatigue tests can be carried out in a number of ways, the way used being the one needed to simulate the type of stress changes that will occur to the material of a component when in service. There are thus bending-stress machines (like the rotating fatigue machine) which bend a test piece of the material alternately one way and then the other as shown in figure 4 below.

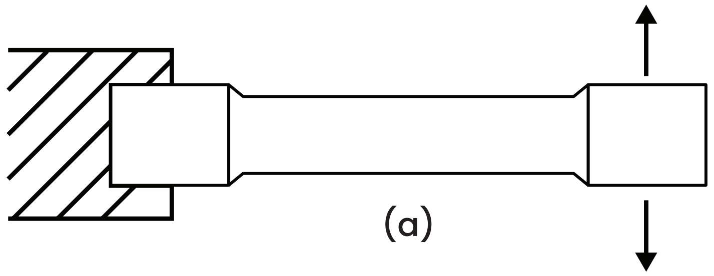


Figure 4

The tests can be carried out with stresses which alternate about zero stress as shown in figure 5 below.

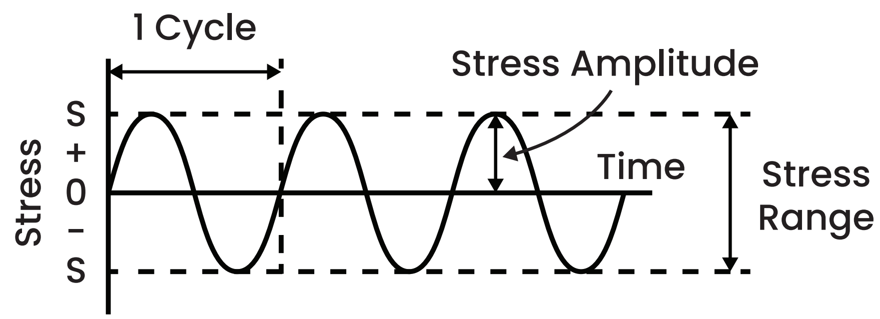


Figure 5

In this case the alternating stress varies between + S and – S. the tensile stress is denoted by a positive sign, compressive stress is a negative sign. Thus the stress range is 2S. The mean stress is zero as the stress alternates equally about the zero stress.

THEORY

Theory

During the fatigue tests, the machine is kept running, alternating the stress, until the specimen fails and the number of cycles (N) of stressing up to failure being recorded by the machine. The test is repeated for the specimen subject to different stress ranges. Such tests enable graphs similar to figure 6 (steel) below to be created.

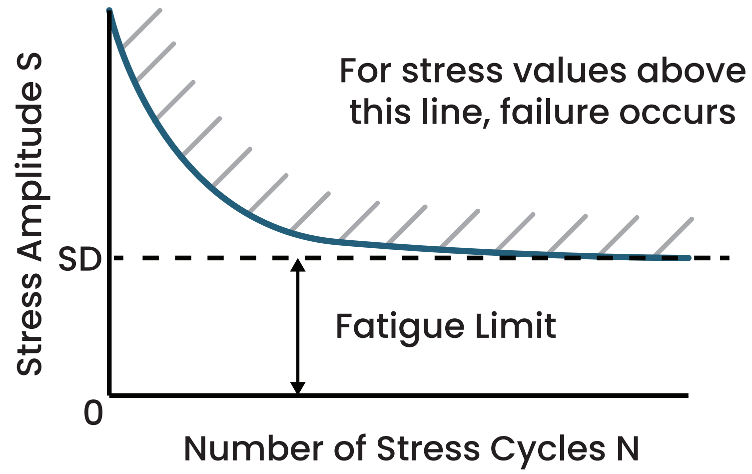


Figure 6 - Steel

The vertical axis is the stress amplitude, half the stress range. For stress amplitude greater than the value given by the graph line, failure occurs for the number of cycles concerned. These graphs are known as S/N graphs, the S denoting the stress amplitude (N/mm2) and the N the number of cycles.

From diagram 6 there is a stress amplitude for which the material will endure an indefinite number of stress cycles. The maximum value, SD being called the fatigue limit. For any stress amplitude grater than the fatigue limit, failure will occur if the material undergoes a sufficient number of stress cycles.

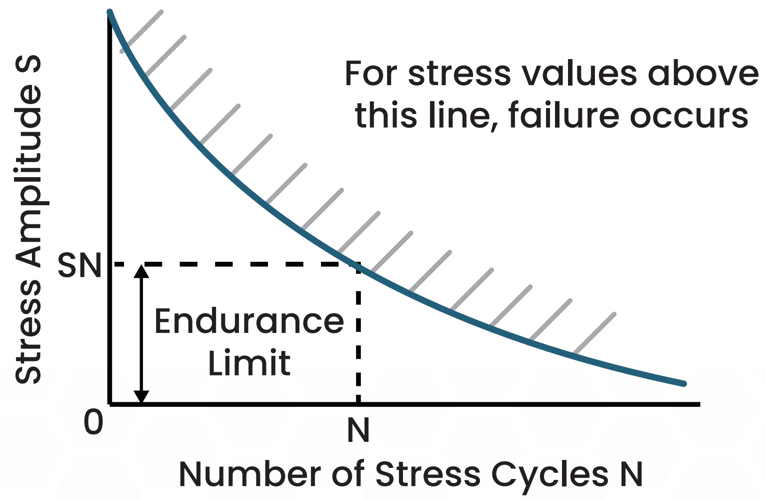


Figure 7 – Non-ferrous alloy

THEORY

Theory

In diagram 7 (non-ferrous alloy) there is no stress amplitude at which failure cannot occur. For such materials an endurance limit, SN is quoted instead. This is defined as the maximum stress amplitude which can be sustained for N cycles.

The number of reversals that a specimen can sustain before failure occurs depends on the stress amplitude. The bigger the stress amplitude the smaller the number of cycles of stress and reversals that can be sustained.

To calculate the stress amplitude first we must calculate the bending stress being applied to the specimen.

From the general formulae for a beam in bending it is written as follows:

$$\frac{M}{I} = \frac{\sigma}{y} \qquad [1]$$

Where:
M = Bending Moment which is equal to Applied Force, F multiplied by the cantilever length, L (Nmm

$$M = F.L \qquad [2]$$

I = Second Moment of Area for a circular cross section (mm4)

$$I = \frac{\pi d^4}{64} \qquad [3]$$

Where
d = diameter of the neck of the specimen (mm)
σ= Bending Stress (N/mm2) (This is the value to be used as the stress amplitude S in the S-N graphs).
y= Distance to the neutral axis of the specimen (mm) which is equal to

$$\frac{d}{2} \qquad [4]$$

Where d = diameter of the neck of the specimen (mm). If the neck diameter of the specimen is nominally 4mm, then y = 2mm.

Rearranging equation 1 in terms of bending stress gives us:

$$\sigma = \frac{My}{I} = \frac{FLy}{I} \qquad [5]$$

Looking at the units for this equation:

$$\sigma = \frac{My}{I} = \frac{FLy}{I} = \frac{N.mm.mm}{mm^4} = \frac{N}{mm^2} \qquad [6]$$

Equation 5 thus simplifies down to:

$$\sigma = \frac{My}{I} = \frac{FLy}{I} = \frac{F.L.32}{\pi.d^3}\left(N/mm^2\right) \qquad [7]$$

EXPERIMENT

Objective / Procedure

Objective

The objective of the experiment is to make an introductory study of fatigue using a Wohler rotating fatigue apparatus.

Procedure

As fatigue fracture experiments may run on for many hours the usual procedure is for each group in a class to set up and start one or two specimens, and for all the results to be shared at the end.

To carry out any meaningful fatigue experiments a consistent set of test specimens must be prepared. The typical standard specimen is shown below. A minimum of 10 specimens for each Part is recommended. They must all be cut from one length of material. In addition at least one tensile test specimen must be taken in order to obtain the lower yield or 0.2% proof stress, the ultimate strength, the elongation on five diameters across the fracture, and if possible the uniform elongation of the material being investigated. For Part 2 it may also be considered useful to test a notched tensile test piece. From the tensile test results the maximum bending stress that can be applied must not be greater than the yield or proof stress, and could perhaps be taken as 0.9 of that test value.

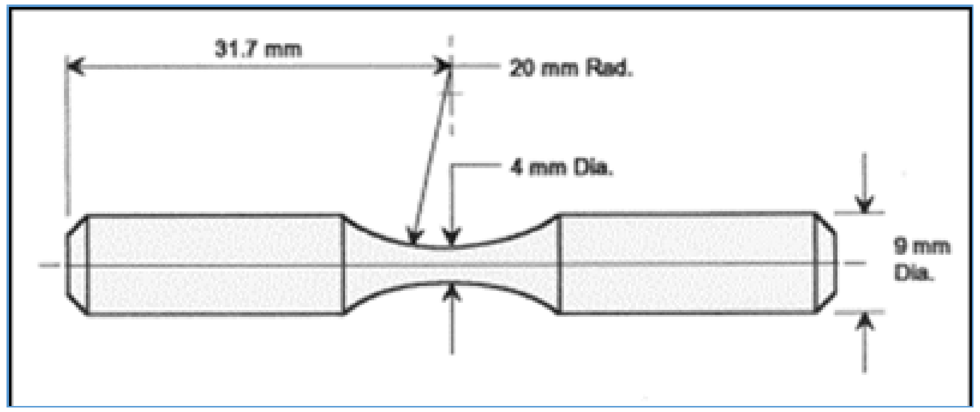


Figure 8 : Specimen Types

Sets of bending stresses from say 0.9 of the yield or proof stress to 0.4 of the ultimate strength should be selected to match the number of test specimens for the complete experiment. The surface condition of the standard specimens should be noted (i.e. as machined, ground, polished). If the equipment is available, measure and record the surface roughness in the direction of the stress. Setting up is a reasonably simple operation provided it is done methodically. The object is to align the specimen and loading arm with the axis of rotation to eliminate stresses due to eccentric whirling.

EXPERIMENT

Procedure

The drive shaft and the loading arm chucks have loose collet grip inserts into which the 9 mm diameter ends of the test specimen are slid as shown in figure 9.

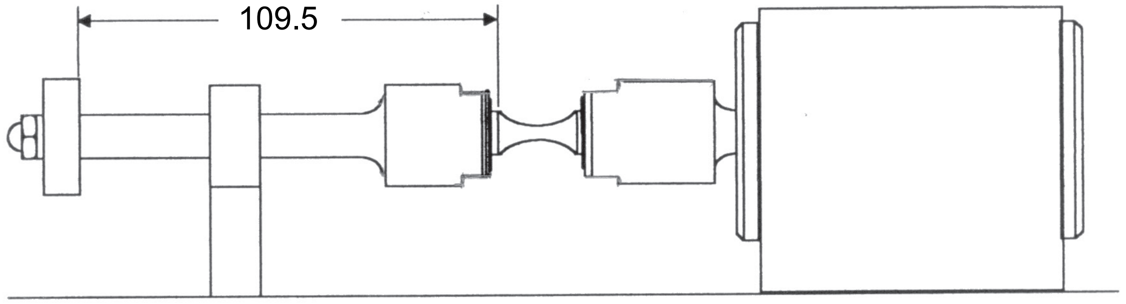


Figure 9 : Specimen Positioning

Firstly tighten the collet on the drive shaft chuck so that the start of the neck of the specimen is flush or under flush with the collet face. Use the 16 and 23 mm spanner provided.
Then push the cantilever shaft onto the other end of the specimen and adjust the collet to give a sliding fit. Now position the cantilever arm so that the dimension of 115 mm is attained from the rear face of the bearing housing to the adjacent end of the neck of the specimen (see figure 9). Adjust the 115mm length if necessary.

Measure the distance from the centre of the load point to the centre of the specimen when arranged at the 115mm position detailed above. This will be dimension L used in equation 7.

Rotate the specimen to check that the end of the cantilever runs true. If it does not, it may be possible to adjust it slightly by realigning the specimen in the chucks or pressing lightly on the end of the cantilever shaft to reduce eccentricity.

If this is not possible the specimen must have got bent and should be discarded.

EXPERIMENT
Objective / Procedure

The following list should be followed in order to run a test:

1. Plug in the sensor connections and turn on the data acquisition box using the rocker switch on the side of the unit. If the software is to be used, connect the USB cable between the box and the PC. Next, power up the box.

NOTE: The plugs and sockets for both sensors are keyed and have different pin configurations. Plugs will only locate into a single socket and in a single orientation- DO NOT FORCE THEM.

2. Connect the power lead to the starter box.

3. Rotate the specimen by hand to check if a count is registered. If this is ok, then reset the count back to zero.

4. Take the load reading and then rotate the screw jack mechanism so that a load is applied to the specimen. Check the force is being registered on the display box. Remove the load.

5. Take the force display again if required.

6. Set the desired load to the specimen by turning the screw jack mechanism. There may be a delay between the loading and force reading on the display unit, allow to settle.

7. Ensure the specimen Microswitch is engaged.

8. Check everything is stable and tight before starting the unit.

9. Close the guard, ensure the guard Microswitch engages.

10. Start the software if required.

11. If the software is used, measurements can be automatically logged to a file. Otherwise record the readings from the touch screen by hand.

12. Check that the count value is zero as no counts have been recorded and the specimen is not rotating. If necessary, touch the Zero button on the screen.

13. When all the data acquisition box is set up and showing the applied force and zero counts, start the motor by pressing the large green button on the starter box of the unit.

14. The force value should remain relatively stable as the specimen is rotating. If the specimen is not sitting/ is fitted precisely square then some fluctuation may occur. The counts display should be increasing both on the touch screen and on the software screen if used.

EXPERIMENT
Procedure

15. If the software is used then the chart should plot the sensor readings.

16. Visually check everything is stable and tight before leaving the unit to run over a prolonged period.

17. When the specimen fractures the unit will automatically turn off. The software will continue to run until turned off by the user. The count will remain on screen. The logging to file function of the software should be stopped.

Notes:

As the onset of fracture approaches the specimen will bend more and this may open the micro switch before complete fracture occurs. In this case move the micro switch down slightly and restart the motor. When the bending stress is at or below the endurance limit for mild steel it may be decided to stop the test at, say, 107 reversals (approximately 30 hours of running time). The result should be noted as NOT FAILED at the recorded count, and the test specimen must be labelled with its history and removed from the apparatus. A similar situation may also arise when an aluminium alloy specimen is subjected to a low bending stress.

Part 1

Using a set of mild steel standard specimens and a similar set of aluminium alloy specimens, allocate the stress levels and tests throughout the class and proceed as above. If time and the number of specimens permits obtain pairs of results at two stress levels of the mild steel and three or four repeats at one stress level with the aluminium alloy material.

Import the results of load versus number of cycles from the data file created prior to testing into Excel. Using the graph option within Excel create a plot of stress range S against number of reversals N allowing the base to run to 108. Note that in the case of a rotating cantilever the stress range is twice the applied bending stress.

Part 2

If time permits and the specimens are available, use a set of notched specimens of the same material as the standard specimens, and proceed as in Part 1.

RESULTS
Results Processing

1. For each loading applied to the specimens calculate the bending stress using equation 7 above. This will be the value for the stress amplitude also.

2. Plot a graph of stress amplitude, S (y-axis) against number of test cycles, N (x-axis).

3. For each value of S and N calculate Log S and Log N.

4. Plot a graph of Log S (y-axis) against Log N (x-axis)

5. Draw a best fit straight line from the higher to lower stress points.

If the results of previous classes are on record compare them with the current set of results. Apart from similarity between the graphs using the ratio instead of the actual stress range can make a better comparison. Differences in surface finish will upset this.

Observations

The graphs for mild steel standard specimens should show an endurance limit. What proportion of the ultimate stress is it? How does it compare with typical elastic design stresses?

What stress level might be just safe for an aluminium alloy component made from the material tested if a fatigue life of 108 reversals had to be withstood?

If the results contain repeated tests comment on their variability. In any event comment on the apparent scatter of each whole set of results from the curves drawn through them. If some results appear to be wild, look at the fractured specimens to see if there are visible reasons.

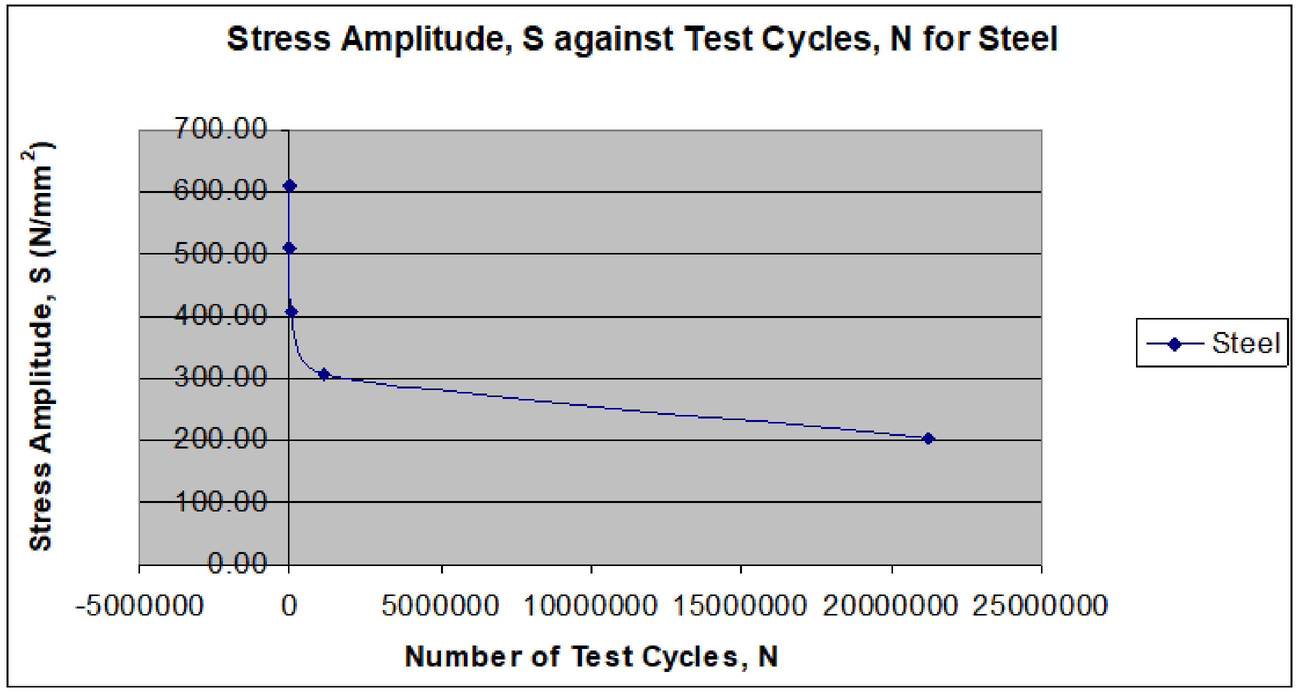
If a set of notched specimens was tested discuss the results in relation to the stress concentration factor of the notch.

RESULTS
Example Results

Steel

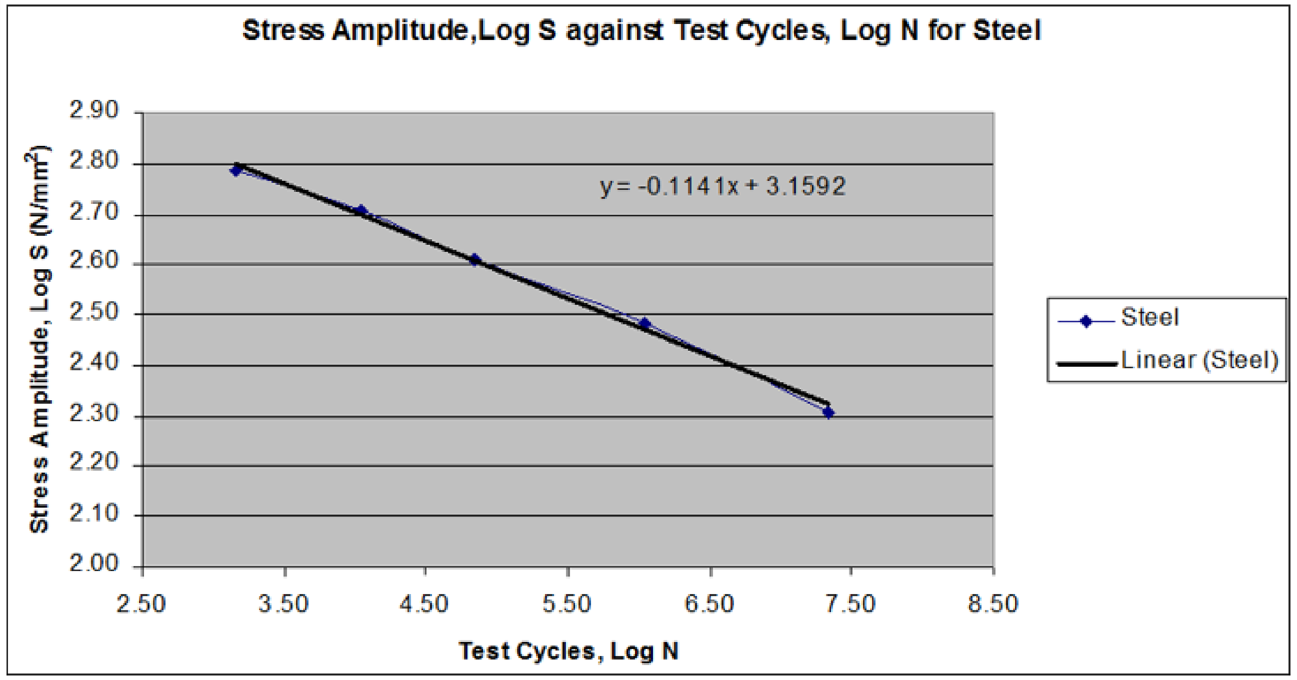
Specimen	Steel
Grade	EN1A
Test Diameter, d (mm)	4.00
Speed, rpm	1400
Cantilever Length, L (mm)	128

	Number of			
Applied Load, F (N)	Test Cycles	Bending Stress, S	Log S	Log N
	N	(N/mm2)	(N/mm2)	
10	21256830	203.72	2.31	7.33
15	1111096	305.58	2.49	6.05
20	68729	407.44	2.61	4.84
25	10902	509.30	2.71	4.04
30	1421	611.15	2.79	3.15



RESULTS

Example Results

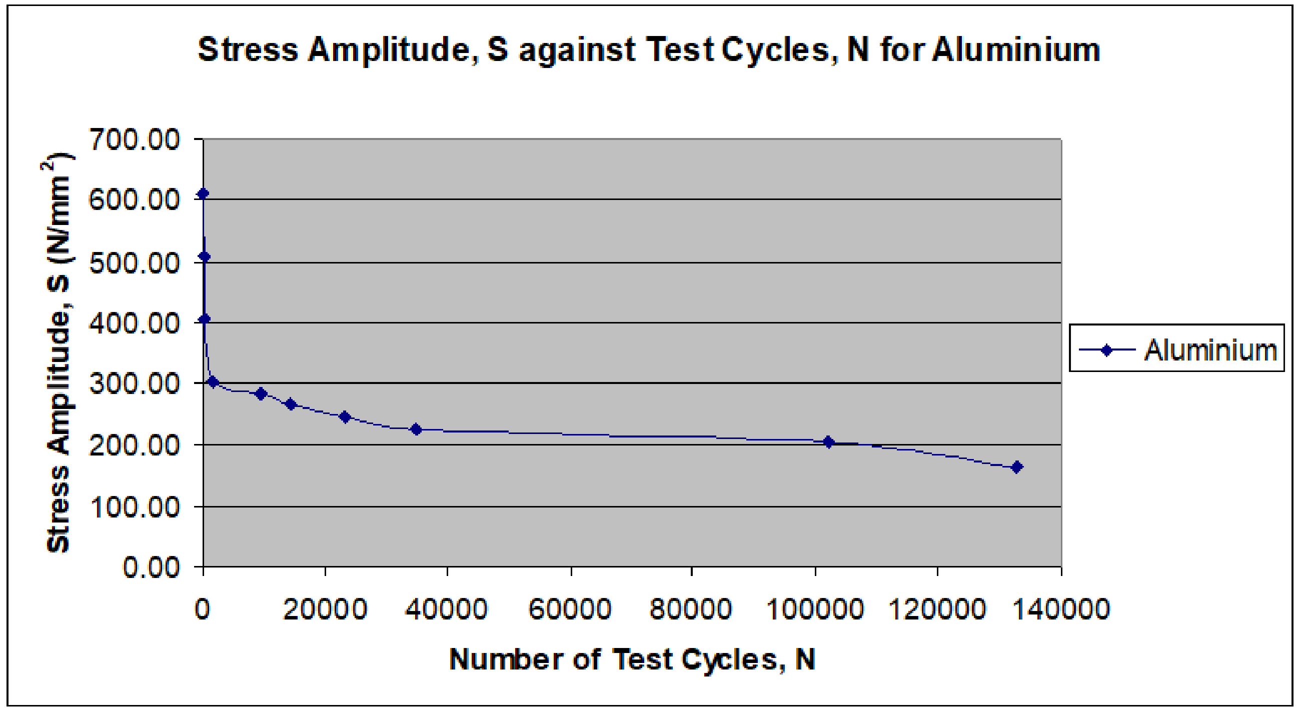


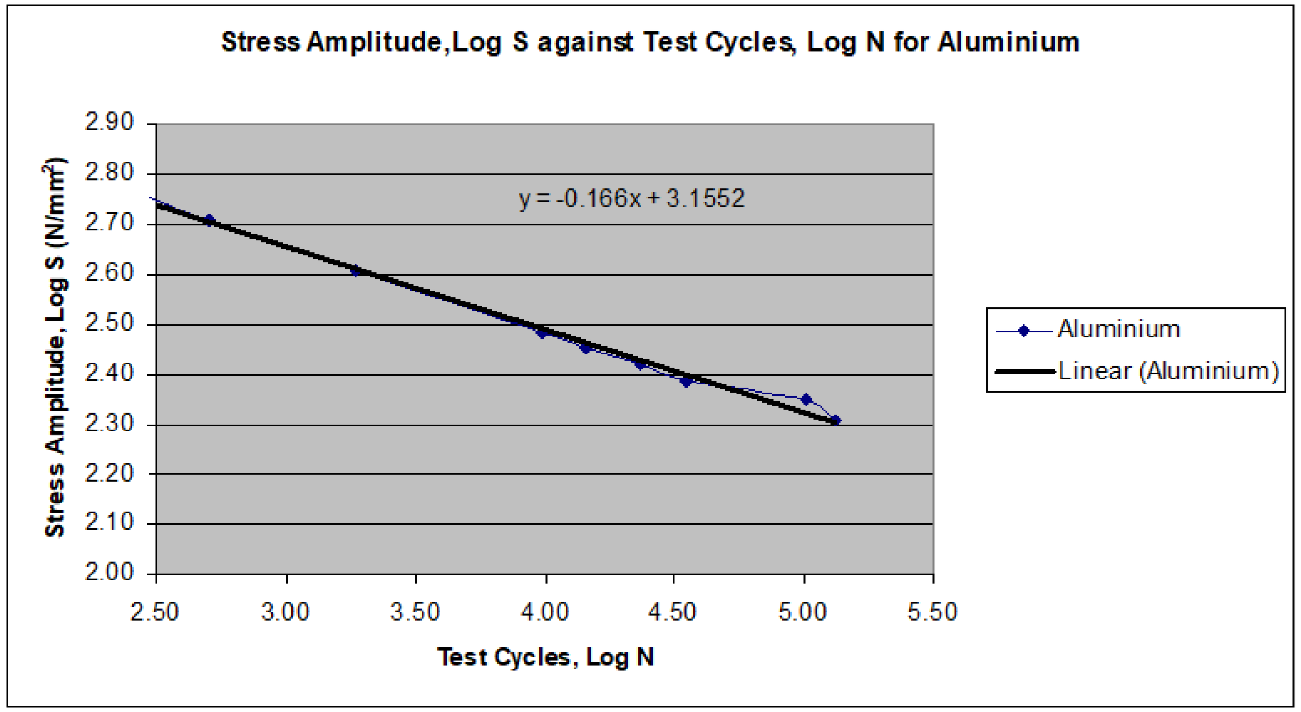
Aluminium

Specimen	Aluminium			
Grade	6082 (HE30)			
Test Diameter, d (mm)	4.00			
Speed, rpm	1400			
Cantilever Length, L (mm)	128			
	Number of			
Applied Load, F (N)	Test Cycles	Bending Stress, S	Log S	Log N
	N	(N/mm2)	(N/mm2)	
8		162.85	2.21	
10	132887	203.57	2.31	5.12
11	102226	223.92	2.35	5.01
12	34943	244.28	2.39	4.54
13	23120	264.64	2.42	4.36
14	14404	284.99	2.45	4.16
15	9696	305.35	2.48	3.99
20	1853	407.13	2.61	3.27
25	503	508.91	2.71	2.70
30	201	610.70	2.79	2.30

SUMMARY OF FAILURE THEORIES

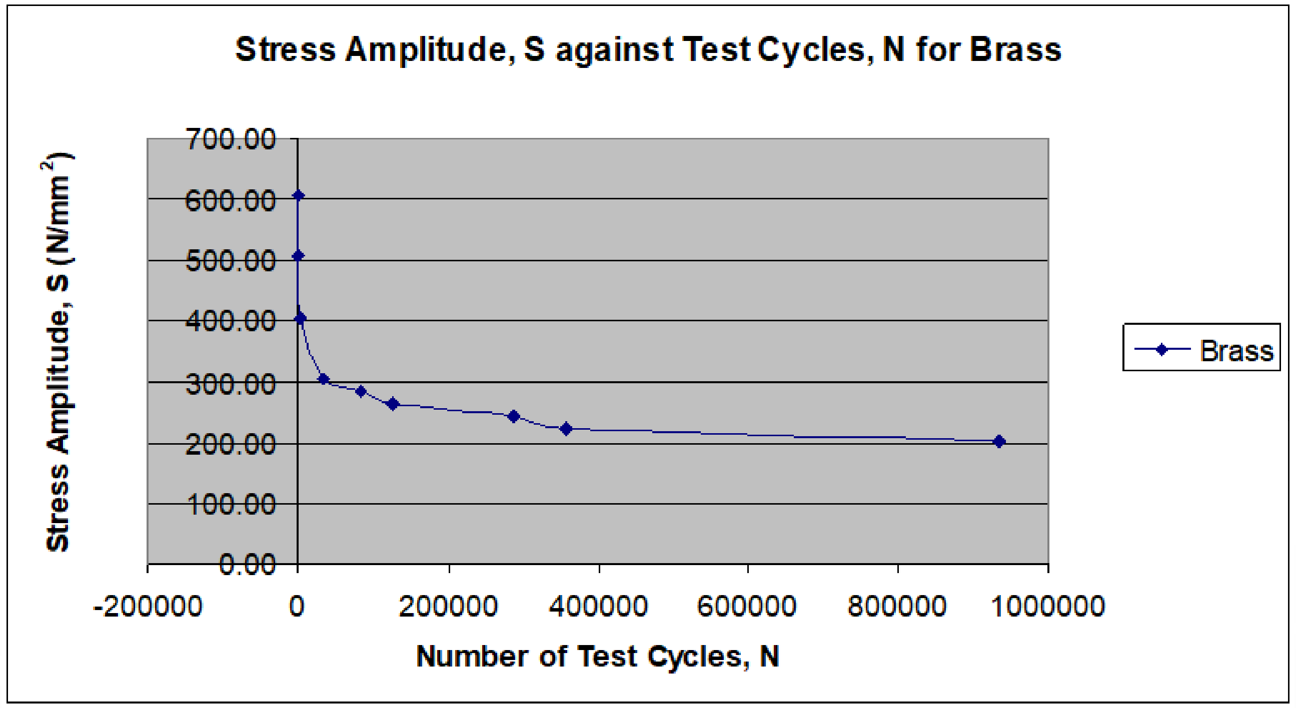
Example Results



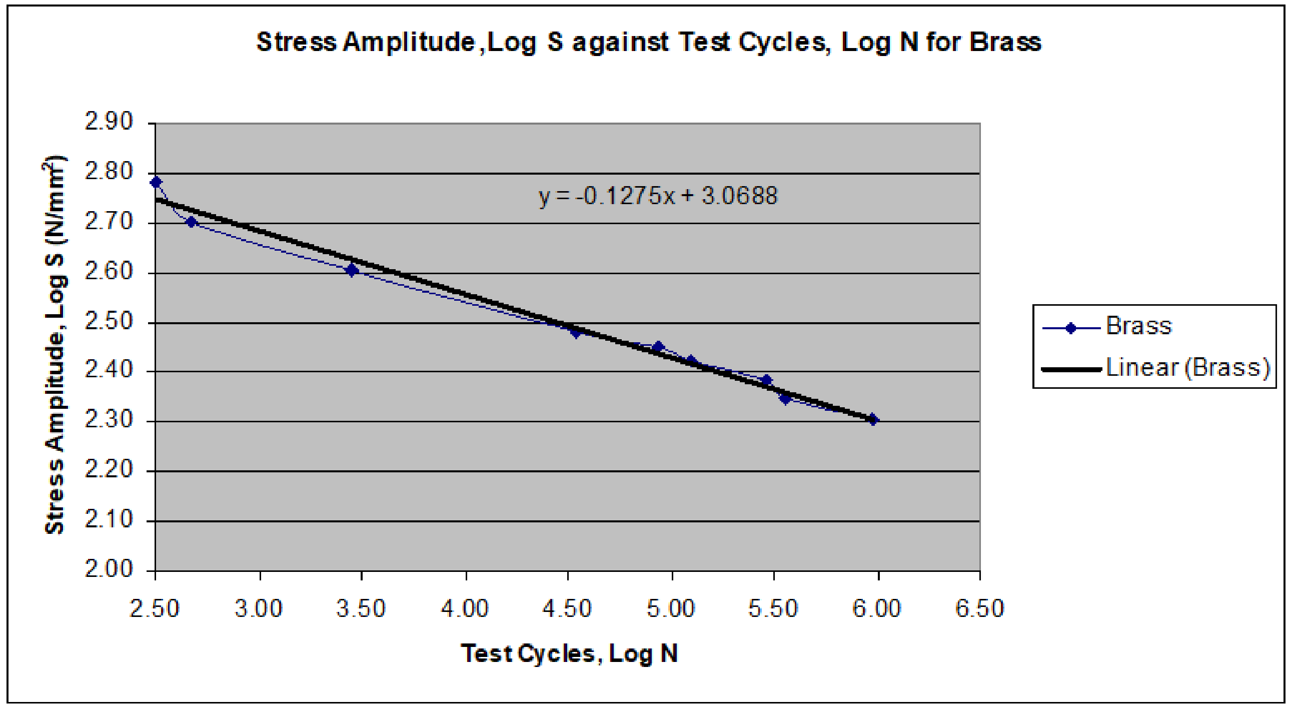


Brass

Specimen	Brass			
Grade	CZ121			
Test Diameter, d (mm)	4.00			
Speed, rpm	1400			
Cantilever Length, L (mm)	128			
	Number of			
Applied Load, F (N)	Test Cycles	Bending Stress, S	Log S	Log N
	N	(N/mm2)	(N/mm2)	
8		162.16	2.21	
10	933003	202.70	2.31	5.97
11	357254	222.97	2.35	5.55
12	288327	243.24	2.39	5.46
13	125617	263.51	2.42	5.10
14	85012	283.78	2.45	4.93
15	34759	304.05	2.48	4.54
20	2846	405.41	2.61	3.45
25	474	506.76	2.70	2.68
30	318	608.11	2.78	2.50



SUMMARY OF FAILURE THEORIES
Example Results



RESULTS
Tables

Steel

Specimen	Steel			
Grade				
Test Diameter, d (mm)				
Speed, rpm				
Cantilever Length, L (mm)				
	Number of			
Applied Load, F (N)	Test Cycles	Bending Stress, S	Log S	Log N
	N	(N/mm2)	(N/mm2)	

Aluminium

Specimen	Aluminium			
Grade				
Test Diameter, d (mm)				
Speed, rpm				
Cantilever Length, L (mm)				
	Number of			
Applied Load, F (N)	Test Cycles	Bending Stress, S	Log S	Log N
	N	(N/mm2)	(N/mm2)	

RESULTS
Tables

Brass

Specimen	Brass			
Grade				
Test Diameter, d (mm)				
Speed, rpm				
Cantilever Length, L (mm)				
	Number of			
Applied Load, F (N)	Test Cycles	Bending Stress, S	Log S	Log N
	N	(N/mm2)	(N/mm2)	

RESULTS

Tables

Table 2 - Elastic Failure Conditions

Row	θ	0º	15º	30º	45º	60º	75º	90º
1	Material A Load (N)*							
2								
3	Material B Load (N)*							
4	R = ØA/ØB							
5	R3							
6	B' Load (N)							
7	(Material A) M (Nm)							
8	T (Nm)							
9	(Material B')M (Nm)							
10	T (Nm)							

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