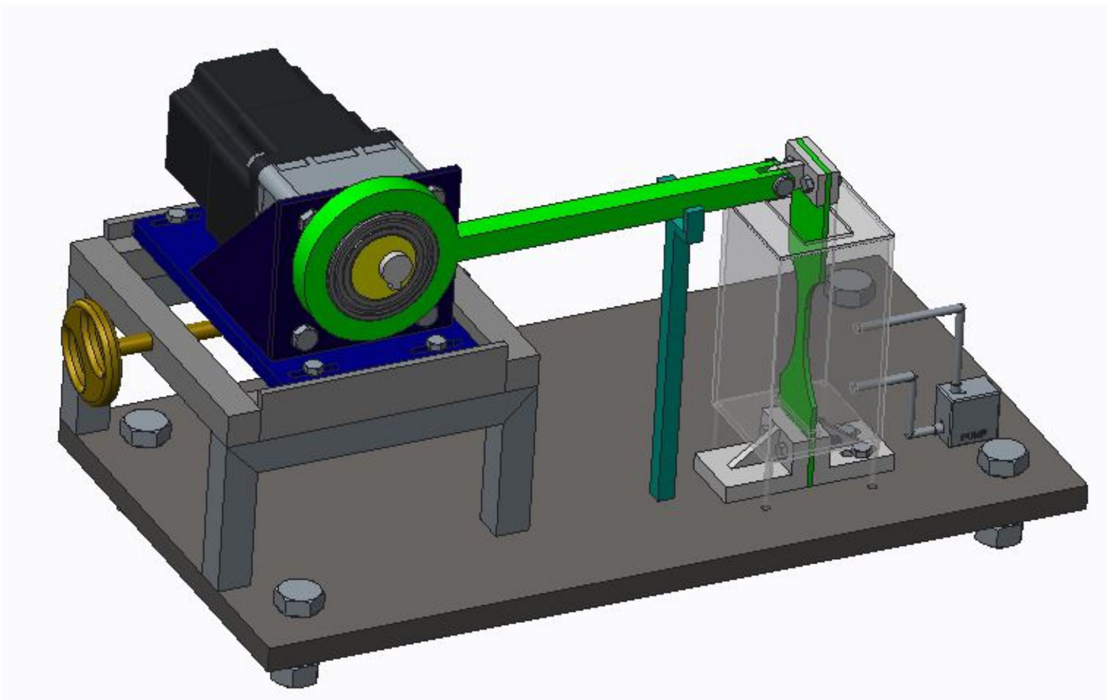
Cantilever Bending – Corrosion Fatigue Testing Machine



Operating Manual

General Safety Precautions

The following general warnings must be complied with at all times when using the corrosion fatigue testing machine.

WARNINGS

1. **Hazard – Press the Emergency Stop button whenever you consider that an unsafe condition exists.**
2. **Flying Debris Hazard – Make sure that test specimens are installed correctly in clamps in order to eliminate stresses that can cause breakage of fixture components.**
3. **Hazard – Protect electrical cables from damage.**
4. **High/Low Temperature Hazard – Wear protective clothing when handling equipment at extremes of temperature.**
5. **Crush Hazard – Take care when installing or removing specimen, assembly or structure.**
6. **Motion Hazard – Keep clear of the moving components unless the component is de-activated.**
7. **Electrical Hazard – Disconnect the electrical power supply before removing the covers on electrical equipment.**
8. **Rotating Machinery Hazard – Disconnecting power supplies before removing the covers on rotating machinery.**
9. **Explosion Hazard – Wear eye protection and use protective shields or screens whenever any possibility exists of a hazard from the failure of a specimen, assembly or structure under test.**
10. **Hazard – Wear protective equipment when draining corrosive fluid to avoid irritation to exposed skin.**
11. **Hazard – Use a crane to lift assembly which is rated to double the capacity of load frame weight.**

Contents

Chapter 1: Introduction

Introduction

This bench mounted corrosion fatigue testing machine is designed to apply cantilever bending to a tensile test specimen of specified size. A 60W Induction Motor provides a controlled speed forcing motion to the specimen enabling oscillation between 0.5-6Hz. Stress amplitude is applied via eccentric bearings; manufactured to provide a range of displacements from 1mm-6mm in 1mm increments. Mean stress is altered using a threaded shaft system, changing the initial displacement of the specimen to a maximum of 6mm from central position and aligned using a vernier scale to an accuracy of 0.5mm. Strain gauges in a full-bridge type II configuration are used to measure the maximum and minimum strain on the specimen to enable the strain amplitude and mean strain to be recorded prior to testing. The mean strain and strain amplitude will be measured in the material elastic region and thus can be converted to mean stress and stress amplitude analytically.

System Description

Main Components

The major components of a cantilever bending corrosion test machine are briefly described below, refer to Figure 1 to understand the location of each component:

Component	Description
Frame Base	A load bearing solid steel plate manufactured from BS970 080M40. 4 holes located in plate to bolt to solid surface to reduce motor vibration.
Frame box section	Load bearing box section, dimensions 20mmx20mmx2mm thick of material BS970 080M40. Frame sections will be connected to each other via welds at 45^{o} angles and welded to the frame base plate.
Motor	60W Induction motor, V Series to be combined with Speed control ES02 (V). Provides rotational motion to the connecting rod allowing sinusoidal motion of specimen.
Eccentric Bearings	Eccentric bearings have machined offset centres to provide displacements of 1-6mm from the original mean position of the specimen. This will provide a variety of test conditions. The eccentric centre is a solid circular steel round to be hydraulically pressed inside the inner ring of a standard bearing.
Connecting Rod	Transfers displacement from the motor to the specimen,

	converting rotational motion to linear motion at the specimen. The connecting rod is manufactured from BS970 080M40. The connecting rod acts as a bearing housing accommodating an oil sealed bearing at the motor and also connects to the specimen clamp via a pin joint connection.
Motor Plate Adjustment	Alters position of the motor to provide an initial displacement (mean strain). The motor will be attached to two rails and the motion controlled via a rotating threaded shaft. The motor is connected to a base plate which has four slots allowing the motor to be bolted into position after adjustment.
Measurement Scale	The movement of the motor and thus the mean strain applied to the specimen will be measured on a graduated marker scale running alongside the motor rails which is to an accuracy of 0.5mm.
Specimen Clamp	Clamp pairs at the base and top of the specimen hold the specimen in place via two holes equally spaced with two bolts tightened to ensure vertical alignment.
Corrosion Chamber	Provides corrosive environment to the gauge length of the specimen in a controlled manner. An acrylic box arrangement with lid to prevent splashing and water evaporation and appropriately sealed via a rubber gasket sealing arrangement.
Water Pump	A 2.8l/min centrifugal micro-pump external to the corrosion chamber recirculates corrosive fluid over the gauge length of the specimen in a controlled manner.
Emergency Stop Button	The emergency stop button is a round, red button located on the control panel. When you press this button, the system shuts off immediately.
Control Panel	The control panel facilitates operating the electronic counting system and the safety shut-off features.
Counter	Electronic counter wired to an optical switch to count the number of cycles to failure. The counter has a maximum counting capacity of 99 999 999.

Table 1: Main components

Number	Part
1	Frame Base
2	Frame Box Section
3	Motor
4	Eccentric Bearing
5	Connecting Rod
6	Motor Plate Adjustment
7	Specimen Clamp
8	Corrosion Chamber
9	Water Pump

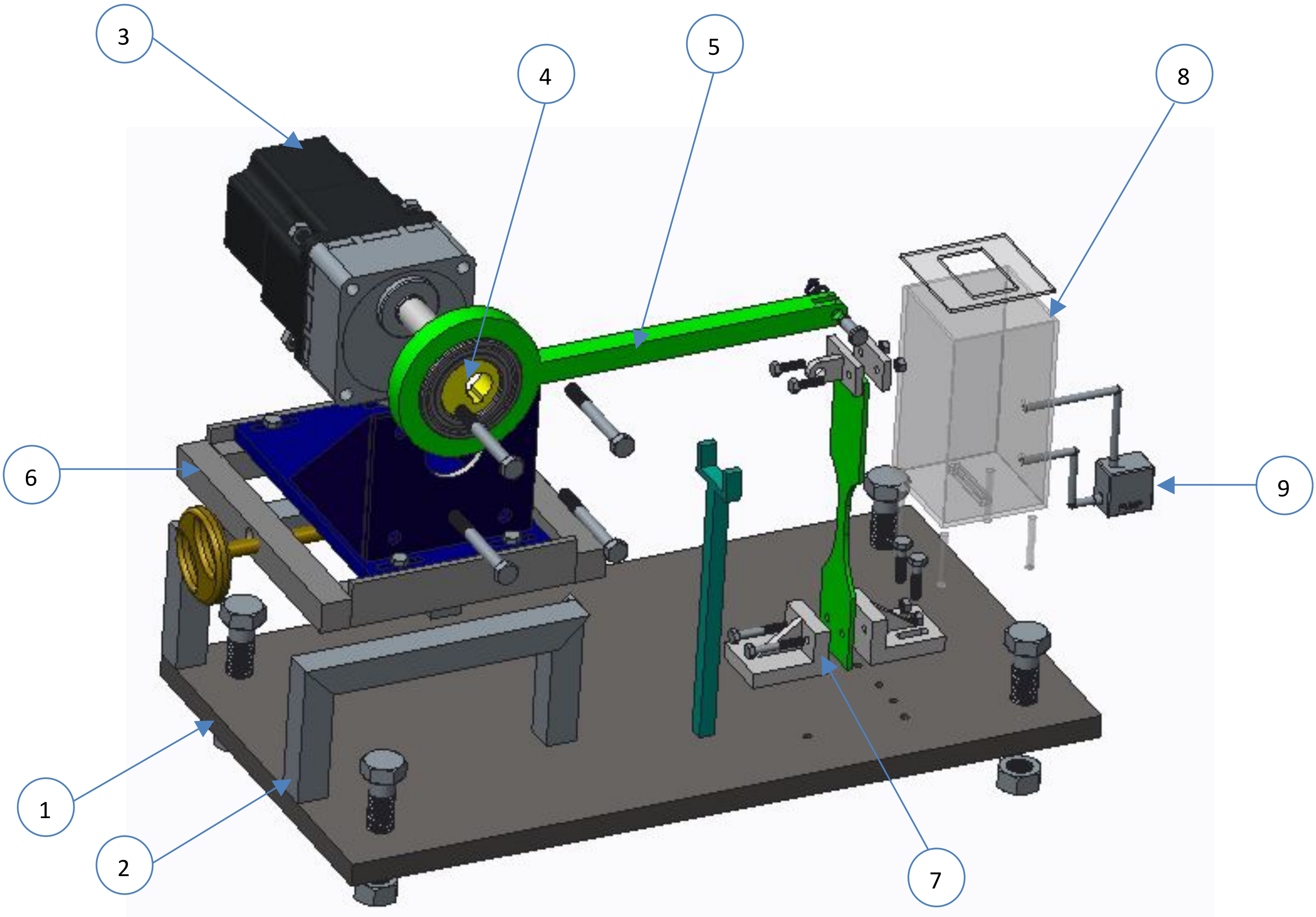


Figure 1: Diagram of Cantilever bending corrosion fatigue testing machine

Chapter 2: Specifications

Environmental Specifications

The cantilever bending corrosion fatigue testing machine is designed for use under normal laboratory conditions, additional protection may be required based on the situation within the laboratory. Environmental conditions for the fatigue testing machine are shown in Table 2.

Parameter	Specification
Operating Temperature	$+10^{\circ}$C to $+38^{\circ}$C
Storage Temperature	-40°C to $+66^{\circ}$C
Humidity	10% to 90% (non-condensing)

Table 2: Environmental conditions

Power Requirements

Motor runs off 50/60Hz mains supply via cable connection.

The pump is a 2.8l/min, 3-12V, vertical flow configuration micro-pump. Power will be supplied by a mains supplied power pack located within the University of Strathclyde Mechanical and Aerospace Department, see Figure 2.

Figure 2: Power supply for micro-pump

Chapter 3: Installation

Installation Guidelines

The following steps below should be followed in order to successfully install said corrosion fatigue testing machine. If the machine is to be transported to site it should be lifted using the appropriate lifting equipment. For the base frame a crane will be required and this should have a lifting capacity of double the weight to be lifted.

Site Requirements

Ensure the following site requirements have been fulfilled before beginning construction of the corrosion fatigue testing machine to ensure as accurate results as possible.

1. The table and floor can support the weight of the machine.
2. The frame is located in an area with air ventilation to dissipate heat generated from the motor.
3. The site is free from vibration from other machinery.
4. There is adequate clearance around the machine operating envelope for servicing. Approximately 1 meter of space on all side of the frame.
5. Electrical source is within 2.5 meters from the motor and pump.

First Time Installation

Prior to the first experiment using the corrosion fatigue machine each component which has been installed will need to be levelled and the dimensions verified. The Manufacturing Manual details specific assembly of parts and the full assembly procedure. Specific components of the corrosion fatigue machine will need to be installed onsite. Follow the procedure below for these individual components.

Component	Installation Procedure
Measurement Scale	1. Secure the measurement scale to the frame so as it corresponds to the movement of the specimen. 2. Ensure that the measurement scale corresponds to the movement of the threaded shaft. 3. The accuracy of the threaded shaft movement can be checked by moving the motor in increments of 0.5mm and verifying that the scale reads the same incremental change.
Corrosion Chamber	1. Place rubber gasket seal inside acrylic container aligning the laser cut holes. 2. Lubricate the specimen and slot it through the gasket and container allowing the gasket to seat. Use caution with this procedure ensuring the holes are aligned and the rubber gasket is undamaged.

	3. Place the acrylic plate on top of the rubber gasket to hold it in place ensure all the holes are aligned. 4. Fashion the gasket assembly in place using M5 nylon screws and a fibre washer on each side to ensure sealing. 5. Test with a small quantity of tap water to ensure the gasket has sealed. 6. Clamp the specimen in position with the bottom clamp arrangement. 7. Connect the water pump using the method specified in the operating manual provided with the pump. 8. Place the lid on top of the box and attach the top clamp to the specimen.
Motor	1. See section 4, 5, and 6 of motor operating manual.
Control Panel	1. Connect the circuits incorporating all components as detailed in Chapter 3: Wiring Counter System and Chapter 3: Wiring Power Supply. 2. Ensure that the control panel has been provided in a ready to use condition. 3. Set up strain gauges on the calibration specimen in accordance with the guidelines in Chapter 3: Wiring Calibration Specimen.
Counter	1. Ensure that the counter is connected to the motor system as detailed Chapter 3: Wiring Counter System.

Table 3: Installation guidelines

Wiring Counter System

The counter system may be wired according to the circuit diagram in Figure 3. Before wiring any components, it may be useful to position the optical switch on the test machine to ensure that the wires leading to and from the switch are long enough to reach the control panel without straining the connections. The optical switch should be placed on the sensor mounting plate such that the switch is horizontally centred and the bottom edge of the switch is flush to the bottom edge of the mounting plate as in Figure 4, this position will ensure the proper distance between the optical switch and the motor shaft. The battery housing should be soldered in place of the actual battery to facilitate easy replacement of the battery. Before soldering any components to the stripboard, the stripboard should be cut in half to produce two 100 x 80 mm boards. This will both reduce the necessary size of the control panel and provide a spare stripboard. The two resistors and the power button should be soldered directly to the stripboard provided. The counter leads are secured using the screw terminals built into the counter. Once the system has been wired, the optical switch may be attached to the sensor mounting plate using an adhesive such as cyanoacrylate.

The final step to complete the counter system involves preparing the motor shaft surface so that it triggers the optical switch once per rotation. In order to do so, the motor shaft directly above the optical switch should first be wrapped in black electrical tape. On top of this tape, a small strip

(~3mm across) of reflective tape should be placed. The reflective tape will act as a trigger for the optical switch, creating a potential difference which can be picked up as an input by the counter.

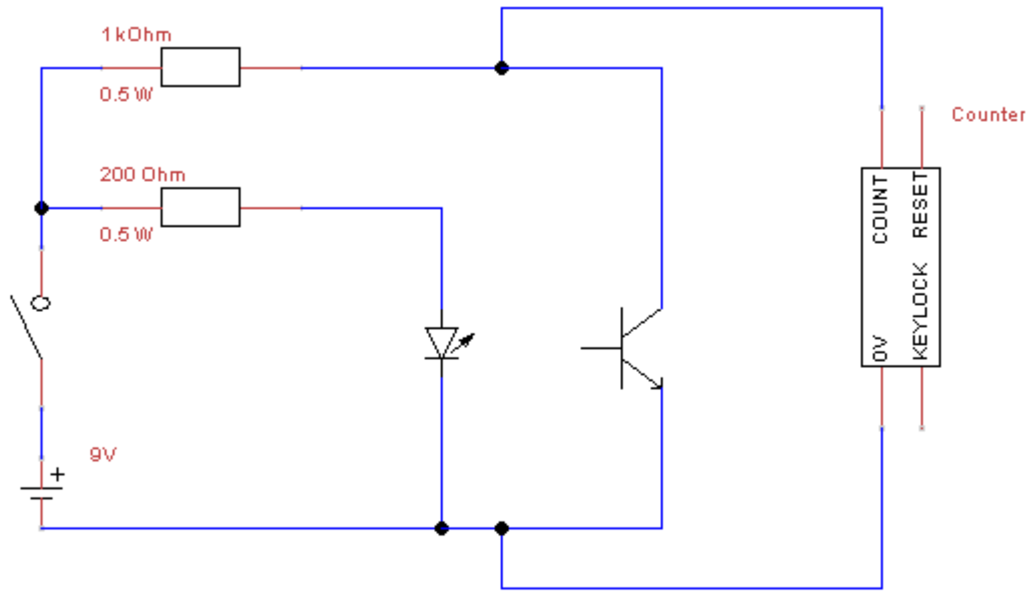


Figure 3: Counter System Circuit Diagram

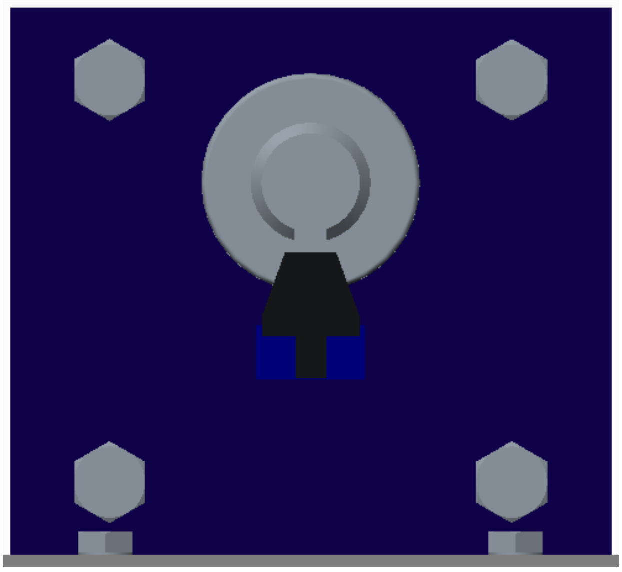


Figure 4: Optical Switch Mounting

Wiring Power Supply

In order to ensure the safe operation of the test machine, there are a number of safety devices which must be wired to the power supply line. To ensure that all components can be wired safely without applying strain to the connections, it is useful to wire the components in order from the motor to the plug.

Motor Connection

The power cable should first be attached to the motor itself. The live and neutral wires are attached at the "CN1" connection. The wires are attached by inserting the wire into the connector while simultaneously pressing the corresponding live or neutral button with a screwdriver. Once the lead wire is inserted, releasing the button will secure the connection. The earth wire is attached to its own connection point using the screw connection on the base of the motor.

Auto Shut-off Switch

The switch responsible for shutting down the test machine at the end of a test cycle should be wired in series with the mains cable. The live wire should be connected to both ends of the switch; one end to the common connection and the other end to the "normally closed" (NC) connection. The auto shut-off switch must be mounted to the top of the connecting rod support arm such that the top edge of the switch housing is flush with the top edge of the arm, allowing the weight of the unsupported connecting rod to depress the switch. Therefore, it must be ensured that the power cable is kept long enough to avoid straining the connection to the switch.

E-stop Switch

Next, the emergency stop switch should be connected in series to the mains cable. Access to the wire terminals is gained by unscrewing the two corner screws on the faceplate and removing the faceplate. As for the auto shut-off switch, the live wire should be connected to both ends of the switch; one end to the common connection and the other end to the "normally closed" (NC) connection. The switch should be attached to the mains cable at a position that allows it to be placed on the control panel without straining the connections.

Circuit Breaker

The Wylex circuit breaker should be connected in series to the mains cable, connecting the live, neutral and earth wires as indicated on the device. The positioning of the circuit breaker is left to the preference of the operator though it is recommended that the circuit breaker be positioned on or near to the control panel.

Plug

Finally, with the other components in place the power cable should be cut at a suitable length and wired to the plug head. The plug may be wired by unscrewing the back face of the plug and attaching the live, neutral and earth wires to the indicated screw connections before reattaching the back of the plug.

Wiring Calibration Specimen

In order to measure the strain across the test specimens for each test configuration, it is necessary to create a "calibration specimen" that includes a wheatstone bridge arrangement for the measurement of strain in the specimen. The calibration specimen is set up using a Full-Bridge Type II Strain Gauge configuration. It is important to correctly attach the strain gauges to the specimen so as to minimise errors in the system. The following instructions outline how to correctly attach and configure the strain gauges required.

Preparing Test Specimen

1. Degrease the gauge length of the specimen using a clean tissue and acetone.
2. Use silicon-carbide paper and metal conditioner to wet abrade the gauge length of the specimen. Abrade the surface until it is bright then wipe dry with a clean tissue.
3. Using a ball point pen and steel rule, mark out the location of the strain gauges with two perpendicular lines for each strain gauge. The steel rule should be cleaned with acetone before bringing it into contact with the test specimen. Note that two strain gauges will need to be attached to each side of the specimen gauge length. On each side of the specimen there should be one strain gauge mounted in the direction of the bending strain and one mounted transverse to the direction of the bending strain.
4. Using a cotton bud, the surface should now be scrubbed with metal conditioner paying particular attention to the layout lines drawn in the previous step.
5. The surface should now be scrubbed with neutraliser to provide optimal alkaline conditions for the attachment of the strain gauges.

Attaching Strain Gauges

Note: the following instruction should be completed fully for one strain gauge at a time.

1. Clean an area of glass for preparation of the strain gauge using acetone.
2. Using tweezers carefully remove the strain gauge from its plastic backing and place it on the glass area.
3. Cover the strain gauge with a piece of clear tape and peel the tape back at a shallow angle, lifting the strain gauge from the glass.
4. Using the tape, carefully position the strain gauge on the test specimen using the previously marked layout lines as a guide.
5. Peel back the tape at a shallow angle leaving one end of the tape attached to the specimen. Loop the loose end over and attach it to the specimen, leaving the area for applying adhesive clear.
6. Before applying adhesive, the user should prepare a sacrificial piece of paper to protect themselves from accidentally becoming attached to the test specimen.
7. Apply a small amount of adhesive such as cyanoacrylate to the test specimen before reattaching the tape. While reattaching the tape, the tape should be smoothed over with a tissue and then light pressure should be applied to the strain gauge using the sacrificial piece of paper to ensure the user's skin does not come in contact with the adhesive.
8. Once the adhesive has dried, slowly peel away the tape.

The above steps should be completed for another three strain gauges remembering that on each side of the test specimen there should be one strain gauge mounted parallel to the direction of bending strain and one strain gauge mounted transverse to the direction of bending strain.

Wiring Wheatstone Bridge

Wiring of the wheatstone bridge circuit can be completed by following the circuit diagram below in Figure 5. The numbering of strain gauges is as follows; R1 and R2 make up one leg of the wheatstone bridge, R3 and R4 make up the other. R1 and R2 are the strain gauges mounted transverse to the direction of bending strain; they act together as a Poisson gauge. R3 and R4 are the strain gauges mounted parallel to the direction of bending strain. The rheostat should be mounted near the bottom of the specimen using cyanoacrylate. All wires used, especially the lead wires to and from the battery housing, should be kept as short as reasonably possible so as to minimise the lead resistance.

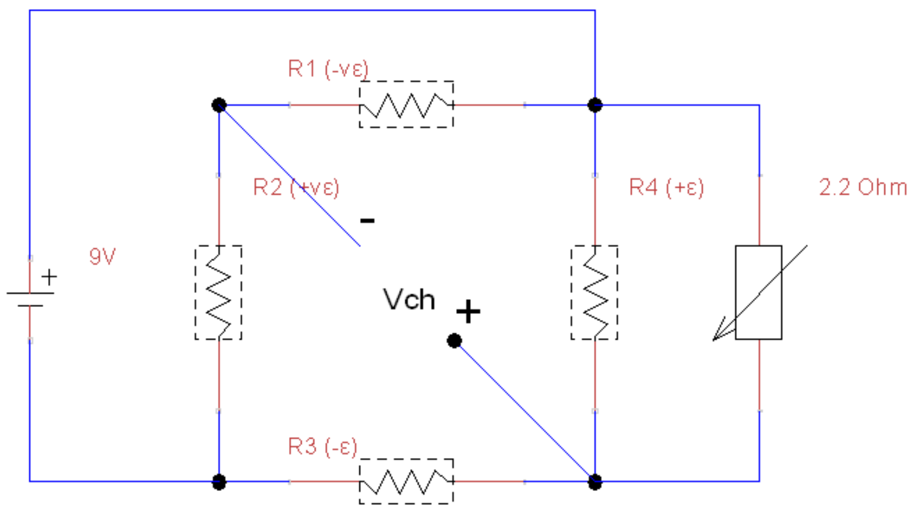


Figure 5: Wheatstone Bridge Counter Circuit

Offset Null

With the circuit completed, a multimeter can be attached across the "Vch" terminals to measure the potential difference between the two arms of the bridge. When the specimen is unstrained, the bridge should be balanced and so the potential difference across the two arms should be zero volts. However, due to an accumulation of small errors this is not usually the case and so an offset null must be carried out. This is accomplished by slowly adjusting the rheostat attached across R4 until the bridge is balanced and the multimeter reads zero volts.

Shunt Calibration

After carrying out the offset nulling described above and balancing the bridge, it is important to verify the accuracy of the system and so a shunt calibration should be carried out. The shunt calibration involves simulating a load across one arm of the wheatstone bridge using a large fixed resistor. The potential difference measured by the multimeter can then be checked against the theoretical value that should be produced.

As shown in the circuit diagram in Figure 6, the shunt resistor should be wired across R3. Note that the resistor does not need to be mounted to the test specimen as it will be removed after the shunt calibration is complete. The ratio of expected signal voltage over supply voltage is defined by the following equation:

$$U = \frac{-R_G}{4R_S + 2R_G}$$

Where U is the voltage ratio, R_G is the nominal gauge resistance and R_S is the value of the shunt resistor.

Using the 40kΩ shunt resistor and taking R_G to be the specified value of 120Ω, the value of U is calculated to be -0.748 mV/V. By recording the voltage produced between the two bridge arms when the shunt resistor is attached, the actual voltage ratio may be determined from the following equation:

$$V_r = \frac{V_{CH}(strained) - V_{CH}(unstrained)}{V_{EX}}$$

Where V_r is the voltage ratio (mV/V), V_{CH} is the voltage measured between the two bridge arms (mV) and V_{EX} is the excitation voltage (V).

The values of V_r and U are then compared with one another. As long as the experimental value of V_r is equal to the calculated value of U, within experimental error, then the wheatstone bridge circuit can be considered accurate enough for use. In the event that the two values cannot be made to match by adjusting the gain on the multimeter, the instrumentation must be considered inaccurate and it may be necessary to recreate the bridge circuit on a new specimen paying particular attention to the placement of the strain gauges in order to minimise inaccuracies in their measurements.

Once the shunt calibration has been carried out, the shunt resistor can be removed from the circuit using a pair of tin snips.

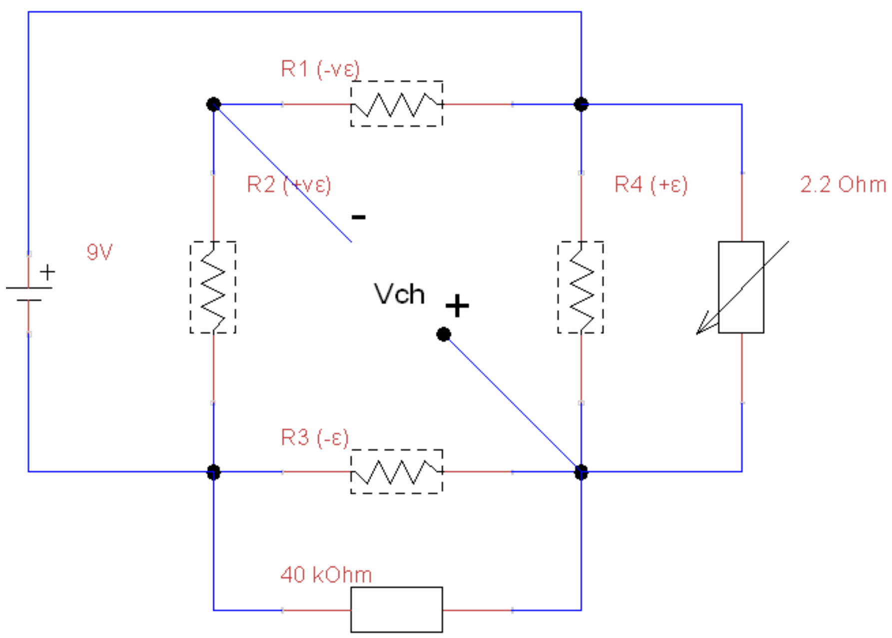


Figure 6: Shunt Calibration Circuit Diagram

Constructing Control Panel

In order to operate the various parts of the test machine it is necessary for a control panel to be built. It is left to the user to decide on the optimum design and layout of this control panel depending on the size/location limits imposed by the chosen testing location. One potential layout, suitable for most applications, is shown below in Figure 10.

1. From the sheet of MDF provided cut a 300 x 150 mm rectangle. This will make up the main part of the control panel upon which the components will be mounted.
2. Cut two more rectangles of 145 x 69 mm. These will make up the panel supports.
3. On the right hand side of the panel support; pencil a mark 30mm from the bottom.
4. Draw a line on the front of the panel support connecting the mark drawn in step 3 to the upper left corner of the support.
5. Cut along the line drawn in step 4, creating the shape shown in Figure 7 below.

Figure 7: Panel Support

6. Repeat steps 3-5 for the other panel support.
7. On the main panel; pencil a mark 70mm from the right hand edge and 15mm from the upper edge.
8. From the point drawn in step 7, create a rectangle extending 60mm left and 10mm down.
9. Using a pillar drill and forstner bit, remove the area of MDF outlined by the rectangle drawn in step 8 leaving a hole as shown in Figure 8 below. This hole will allow the counter to be mounted using its clamp mounting system.

Figure 8: Main Control Panel

10. Using a suitable adhesive such as cyanoacrylate, glue the panel supports to either end of the main panel creating the full control panel as shown in Figure 9 below.

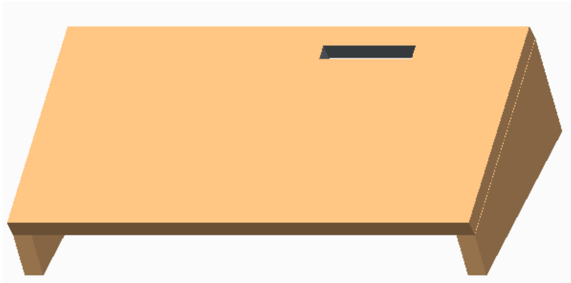


Figure 9: Final Control Panel

With the control panel constructed, the various components can be mounted to the panel. The recommended layout for the components is shown below in Figure 10.

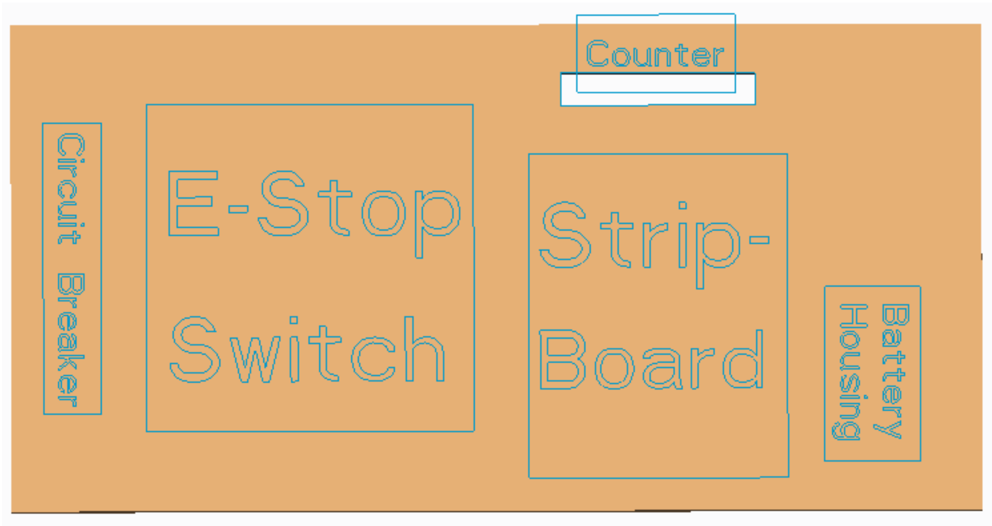


Figure 10: Component Placement

The components may be attached to the control panel using a suitable adhesive such as cyanoacrylate with the exception of the counter which has a clamp system built in. The hole drilled in the main panel can be used to allow the counter to clamp onto the edge while keeping the counter screen parallel to the control panel surface.

Chapter 4: Operation

Basic Operation

The basic operation of the cantilever bending corrosion fatigue machine involves:

1. Control frequency of test using motor control system
2. Control velocity of fluid by voltage input of micro-pump
3. Proper eccentric bearing selection for desired strain amplitude
4. Motor adjustment to apply desired mean strain
5. Installing a specimen
6. Starting a test and applying a load to a specimen
7. Measuring the results of the test

Test Set-up

Before starting a test ensure that you understand the basic features of the cantilever bending fatigue testing machine, see Chapter 1.

Start-up Procedure

1. Ensure all cables are properly installed and securely connected for both the motor and the pump.
2. Ensure that the power supply circuit breaker is not tripped and the E-stop and auto shut-off switches are in the closed position.
3. Set the motor frequency to the desired sinusoidal value for test. Recommendation for this machine is between 0.5-6Hz. Record the chosen value.
4. Set the voltage input for the pump to control the velocity of recirculating corrosive fluid.
5. Adjust the motor to the zero position on the measurement scale using the threaded shaft arrangement.
6. Choose the desired test condition. The specimen can have a sinusoidal displacement from 1mm to 6mm in 1mm increments. There are individual eccentric bearings that provide this amplitude. Insert the eccentric bearing inside the bearing housing on the connecting rod using a hydraulic press. Support the assembly to ensure there is no damage to the specimen, for more details see Manufacturing Manual.
7. Insert calibration specimen with strain gauges which have been attached using the procedure detailed in Chapter 3: Wiring Calibration Specimen.
8. Ensure the bottom of the calibration specimen base is flat against the base of the bench as this has been previously levelled.
9. Hold the specimen firm against the front base clamp and tighten the specimen in place using the nuts and bolts provided. Tighten in accordance with Table 4.
10. Attach the top clamp to the top of the specimen as in step 8.
11. Read the strain measurement using the procedure detailed in Chapter 4: Taking Strain Measurements and ensure that the scale is at zero.
12. Now use the threaded shaft and measurement scale to move the motor to the desired offset initial displacement for the test. The specimen can be offset up to 6mm and still be within

the elastic region of the material for SS316, SS4330 and carbon steel. If other materials are required to be tested additional calculation will be required.

13. When the motor is in place read the placement of the motor on the measurement scale and the strain reading. Record this.
14. Bolt the motor in place through the slots in the motor plate. Tightening the nuts and bolts as in Step 3.
15. Turn the motor shaft by hand ensure that it is powered down. This will move the specimen to the maximum and minimum position. Read and record the maximum and minimum strain recorded from the strain gauge to determine strain amplitude and mean strain.
16. Return the motor to the zero position on the measurement scale.
17. Ensure that the strain reading has again returned to zero.

To set-up the corrosion chamber with test specimen:

18. Inset laser cut rubber gasket inside acrylic box and align the holes in each.
19. Lubricate the specimen and insert the test specimen through the allotted slot with caution to ensure the rubber gasket is undamaged. The gasket will then be allowed to seat.
20. Insert the acrylic plate on top of the rubber gasket and align the holes.
21. Insert the 8 Nylon M5 bolts into the holes with a fibre washer on each side. Tighten to ensure sealing.
22. Trial the gasket sealing arrangement with tap water to ensure the seal has been effective.
23. Place the specimen within the base clamp and repeat Steps 7 and 8.
24. Place the lid on top of the acrylic container in correct orientation to allow cantilever motion of specimen.
25. Repeat Step 8 for the top clamp.
26. Connect the tygon tubing through the outlet and inlet holes. Seal using appropriately sized O-rings.
27. Fill container with chosen corrosion fluid for test. Measure the volume of fluid in corrosion container via the marking system on the container. Record this volume.

To start the test:

28. Adjust the motor to the same position on the measurement scale as was defined by the calibration specimen.
29. Double check that all components are connected and secure.
30. Set the speed of the motor on the digital display (see section 7 of motor operating manual).
31. Switch on the optical switch.
32. Switch on and reset the counter.
33. Start the motor.
34. Start the pump to recirculate the fluid.
35. Record the start time of the test and temperature of corrosive fluid.

Nominal Diameter	Torque (Nm)
M5	4-6
M6	7-10
M8	16-24
M16	170-220

Table 4: Tightening specifications

Stopping a Test

Automatic Procedure

Under normal operating conditions the motor will switch itself off upon completion of a test.

1. When a test specimen has failed, the connecting rod will be left unsupported and will drop onto the arm stand.
2. In doing so the connecting rod will depress the power switch attached to the stand, cutting off power to the motor.
3. Before making adjustments to the test machine, the operator should ensure that no electricity is flowing in the power supply by disconnecting the power supply from the mains source.
4. Before beginning another test, the operator should ensure that the power switch attached to the arm stand is reset to the ON position to allow power to be supplied to the motor.

Emergency Stop Procedure

In the event of an emergency situation, the operator should immediately depress the RED KILL SWITCH located on the control panel. This switch will immediately cut power to the motor. Before beginning another test, the operator should ensure that the kill switch is returned to the closed position to allow power to be supplied to the motor.

Taking Strain Measurements

Using the calibration specimen described in Chapter 3: Wiring Calibration Specimen it is possible to measure the maximum and minimum strain values that a specimen will experience in a given test configuration. These strain values can then be converted to stress values for the construction of S-N curves.

Before taking any measurements, the test machine should be set up with the desired test conditions and with the calibration specimen in place as in Chapter 4: Operation: Test Set-up.

Once the correct eccentric bearing has been installed and the motor has been moved into the desired position, strain measurements may now be taken as follows:

1. Connect the battery to the calibration specimen.
2. Rotate the motor bearing by hand until the calibration specimen has experienced both it's maximum and minimum loading.

3. Rotate the motor bearing by hand until the calibration specimen is in it's minimally loaded position i.e. the specimen is experiencing the minimum displacement that the chosen test configuration will allow. Allow the circuit some time to stabilize.
4. Connect a multimeter across the two arms of the wheatstone bridge circuit i.e. the two terminals marked "Vch" in Figure 5.
5. Note down the voltage measured by the multimeter.
6. Repeat steps 4 and 5 when the specimen is in it's fully loaded position.
7. Disconnect the battery from the calibration specimen.

These voltage values can now be converted into strain readings which can in turn be converted into stress readings as outlined in Chapter 4: Operation: Recordable Results. First, the ratio of measured voltage over excitation voltage is calculated from the following equation:

$$V_r = \frac{V_{CH}(strained) - V_{CH}(unstrained)}{V_{EX}}$$

Where V_r is the voltage ratio (mV/V), V_{CH} is the measured voltage (mV) and V_{EX} is the excitation voltage (V).

Since the wheatstone bridge circuit has been offset nulled, the value of V_{CH}(unstrained) should be zero volts so the above equation simplifies to

$$V_r = \frac{V_{CH}}{V_{EX}}$$

Once the voltage ratio has been calculated, the corresponding strain value may be calculated using the following equation:

$$\varepsilon = \frac{-2V_r}{GF(1+v)}$$

Where ε = strain, GF = gauge factor (2 for the strain gauges supplied) and v = Poisson's ratio of the specific material in use.

By carrying out the above calculations using the maximum and minimum load values of V_{CH} the values of maximum and minimum strain the test specimen will experience can be found. These values should be recorded and the mean strain calculated as follows:

$$mean\ strain = \frac{minimum\ strain + maximum\ strain}{2}$$

Recordable results

The following Table shows the parameters that should be recorded for each experiment:

Start date & time	Eccentric bearing size	Offset Dimension	Strain at mean position	Maximum strain	Minimum Strain	Motor frequency	Pump velocity	Number of cycles to failure

Table 5: Results Table

Examples of the results that will be generated from the cantilever bending corrosion fatigue testing machine are shown in Figure 11 & 12. For each test condition the strain amplitude and mean strain will be controlled and recorded and the number of cycles to failure recorded. The corrosive fluid concentration, velocity and temperature will be recorded to ensure reliability between experiments.

The mean strain and strain amplitude is converted to mean stress and stress amplitude using the equation below.

$$\sigma = E\varepsilon$$

Where: σ = stress (N/mm^2)

ε = strain (μ ε)

E = Young's Modulus (N/mm^2)

The following S-N curve and constant-life diagram can be produced from the cantilever bending corrosion fatigue testing machine:

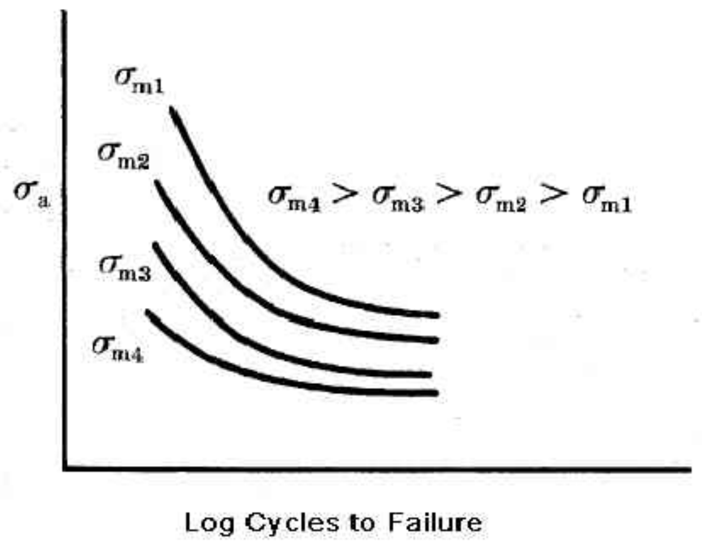


Figure 11: S-N Curve showing potential results

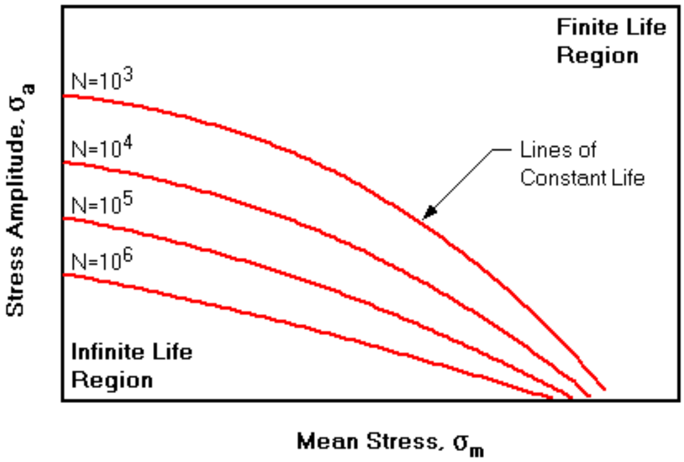


Figure 12: Constant Life Diagram

Chapter 5: Maintenance

Introduction to Maintenance

Maintenance of the machine is essential to ensure the long life-cycle of the machine. To ensure the machine continues working at its optimal performance, it is recommended that the rotating components of the machine receive an annual service check.

Daily Maintenance Checks

Before operating the system the following should be checked:

- All cables are tight and secure.
- All clamps and fixtures are free of dirt, damage or deformation.
- Ensure that the strain gauges are correctly attached to the calibration specimen.
- Ensure that all parts requiring lubrication are greased.

Periodic Inspections

Every six to twelve months, perform the following operations:

- Visually inspect for any loose fittings or wear on components.
- Check the operation of the motor and water pump.
- Calibrate the measurement scale encase of wear on the threaded shaft.

Cleaning

It is recommended that the machine be cleaned bi-weekly to remove any unwanted dust or dirt.

- Wipe frame and exposed equipment with a damp cloth.
- Clean acrylic container with tap water to remove corrosive residue.

Lubrication

- Bearing and bearing housing are to be lubricated prior to each test.
- Specimen is to be greased prior to seating in rubber gasket.
- Lubricate the pin joint connecting the connecting rod to the top clamp every 3 days while the test is in progression.