Introduction to Using a Servo Hydraulic Test Machine

Andreas T. Echtermeyer

Norwegian University of Science and Technology, NTNU
Trondheim, Norway

Andreas.Echtermeyer@ntnu.no

Version: 2021/01/25

CONTENTS

- Principle of the machine
- Safety for you and others
- Protect the machine
- What do we control and how
- Quality testing

Servo hydraulic Test Machine

50 kN (5t) Machine at NTNU-MTP

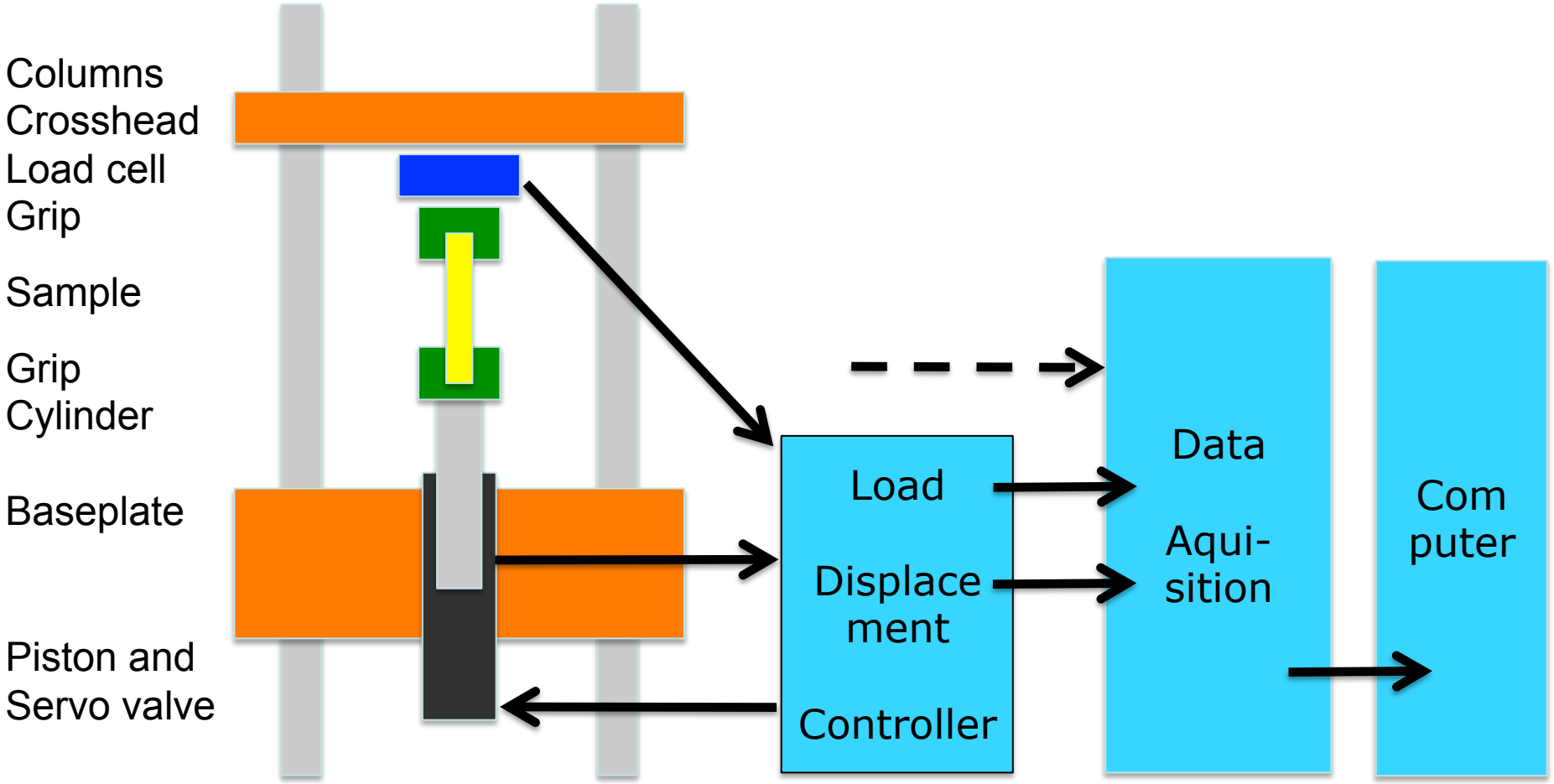
Examples of Test Machines

1000 kN (100 t) Machine at NTNU-KT

2800 t Machine at DNV-Bergen

Testing an Airplane

Principle of a test machine



Safety

- Know where the emergency power off switch is.
- Be careful when fingers/body are in the load path.
- If you operate the machine, check that the load path is clear.
- Do not get close to the loaded specimen.
- Always set machine limits!
- A breaking specimen may shoot out particles.
- Put a screen between you and the specimen.
- Watch out that others cannot be hit by particles.
- Make sure the crosshead is tight.
- Are test materials and fluids safe?
- Be careful with hydraulic hoses, check that they are OK.

Risk Assesment

All work you do must be covered by a risk assessment! It is your (the student´s) responsibility that you have this risk assessment filled out and SIGNED.

It must be signed by you, your advisor, the lab responsible and the lab leader. It will take some time to get the four signatures, so plan ahead!

A copy of the signed risk assessment shall be available in the lab AND shall be sent to the lab responsible.

Order - Tidyness

Keep the lab tidy! It is best for you and your colleagues.

Simple Test and Specimen Example

Tensile Test - Example

Unidirectional composite in fiber direction

Expected strain to failure 2.5%

Expected strength 400 MPa

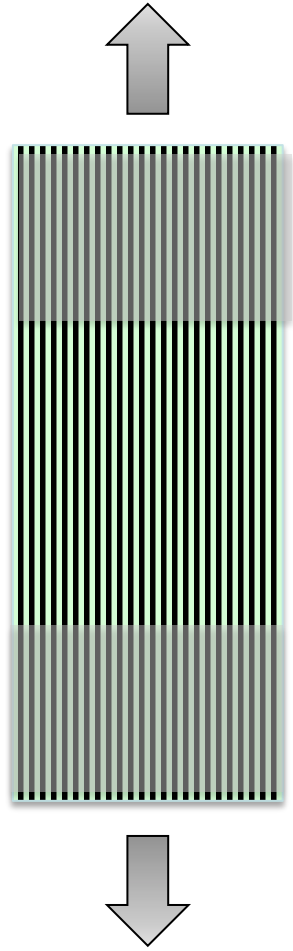
Dimensions 300(200)x25x2 mm

*Strain rate: 1.67 10^{-4} / sec**

Failure load: 20 kN

Displacement to failure: 5 mm*

Displacement rate: 2 mm /min



* *calculated based on 200 mm gauge length and displacement rate (need to measure it directly, if you need it accurately)*

Preparations

Select Test Machine

Load capacity higher than your expected failure load.

Displacement higher than your expected failure load.

Testing speed capability exceeds your loading rate needs.

Machine big enough to take your specimen.

Check availability.

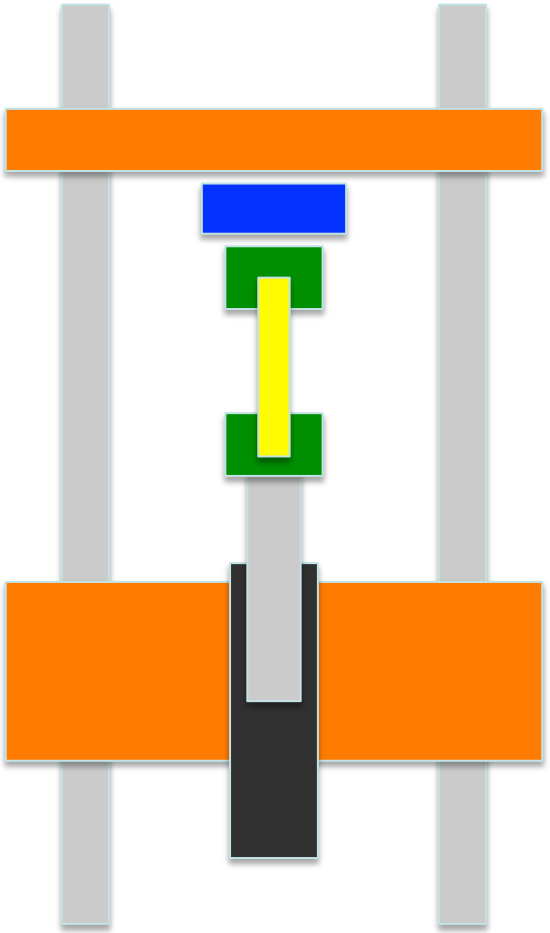
Sometimes it is smart to redesign your test program and *samples* in order to get a test machine that has better availability.

Note: Usually several machines are perfectly fine for the job.

Select Grips

Grips must be able to hold your sample. Sometimes specific grips are required. Often you have a wider choice.

Not all grips fit into all machines -> you may have to choose a different machine.



Samples

Preferably, run your test on a dummy sample first.

Use your precious real samples when you are sure everything works.

Try to make more samples than you intend to test. Some things tend to go wrong when testing, having some spares is good.

Last but not least → have your samples ready!

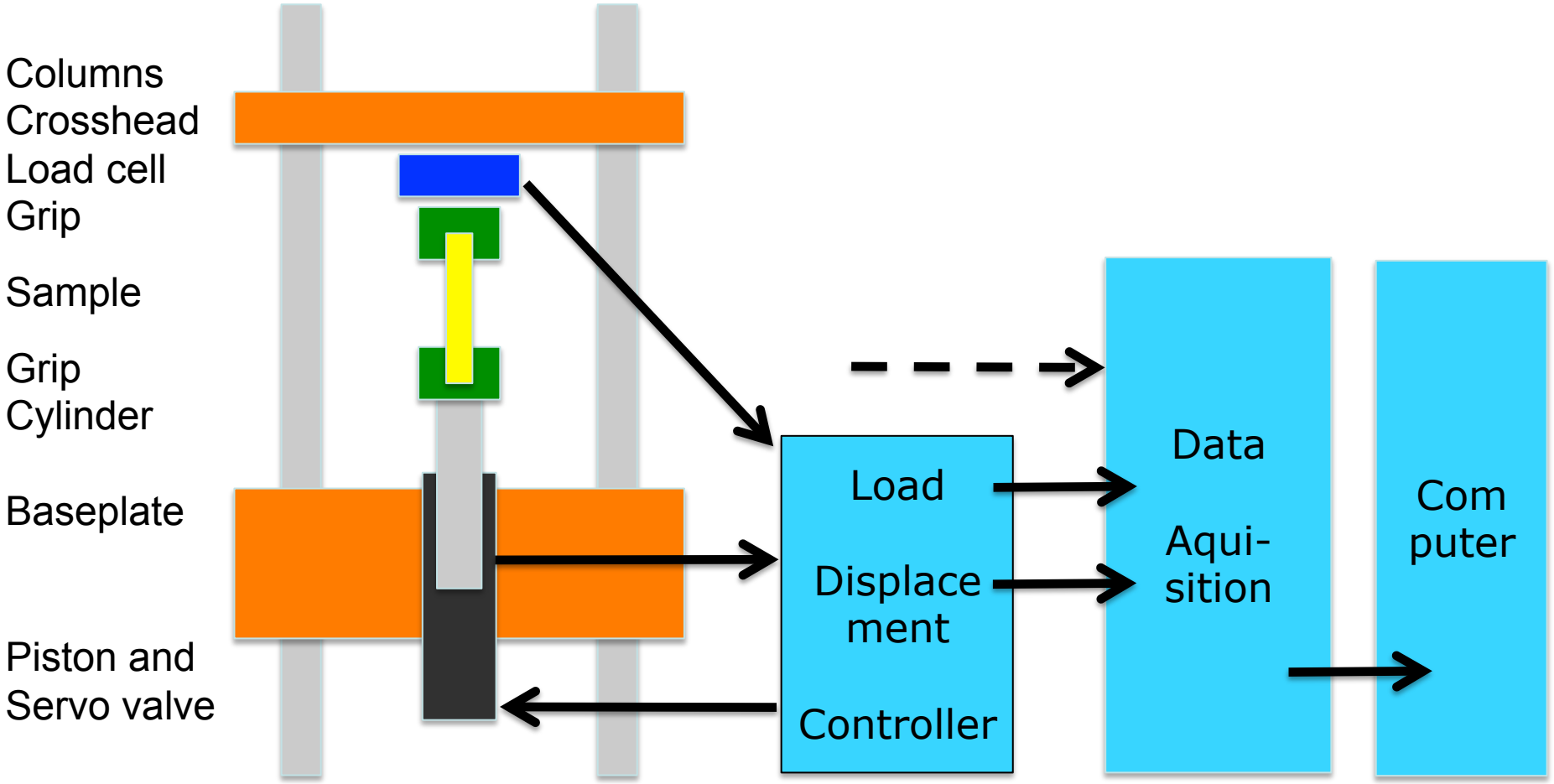
Install Grips

Decide on which grips to use. Install the grips when the test machine is switched off.

You need help from the lab engineers to install or modify grips, unless you are an “expert” user.

Basic Settings

Principle of a test machine



Displacement or Load Control

Only either the load signal or the displacement signal can be used to control the machines.

Other “advanced” options may be available, but are not covered here.

For (quasi)static tensile tests we usually choose displacement control.

For fatigue testing we usually choose load control.

Tensile Test - Example

Unidirectional composite in fiber direction

Expected strain to failure 2.5%

Expected strength 400 MPa

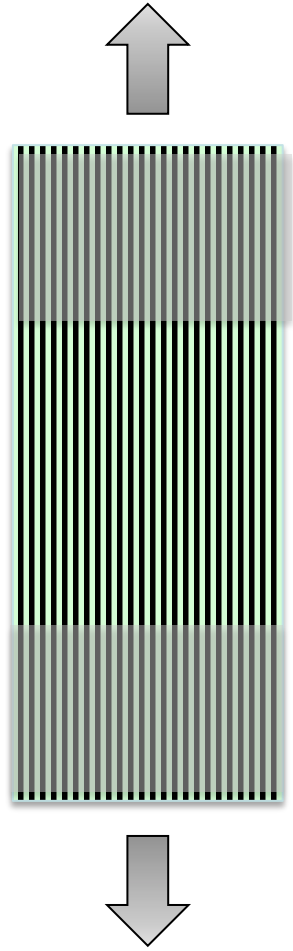
Dimensions 300(200)x25x2 mm

*Strain rate: 1.67 10^{-4} / sec**

Failure load: 20 kN

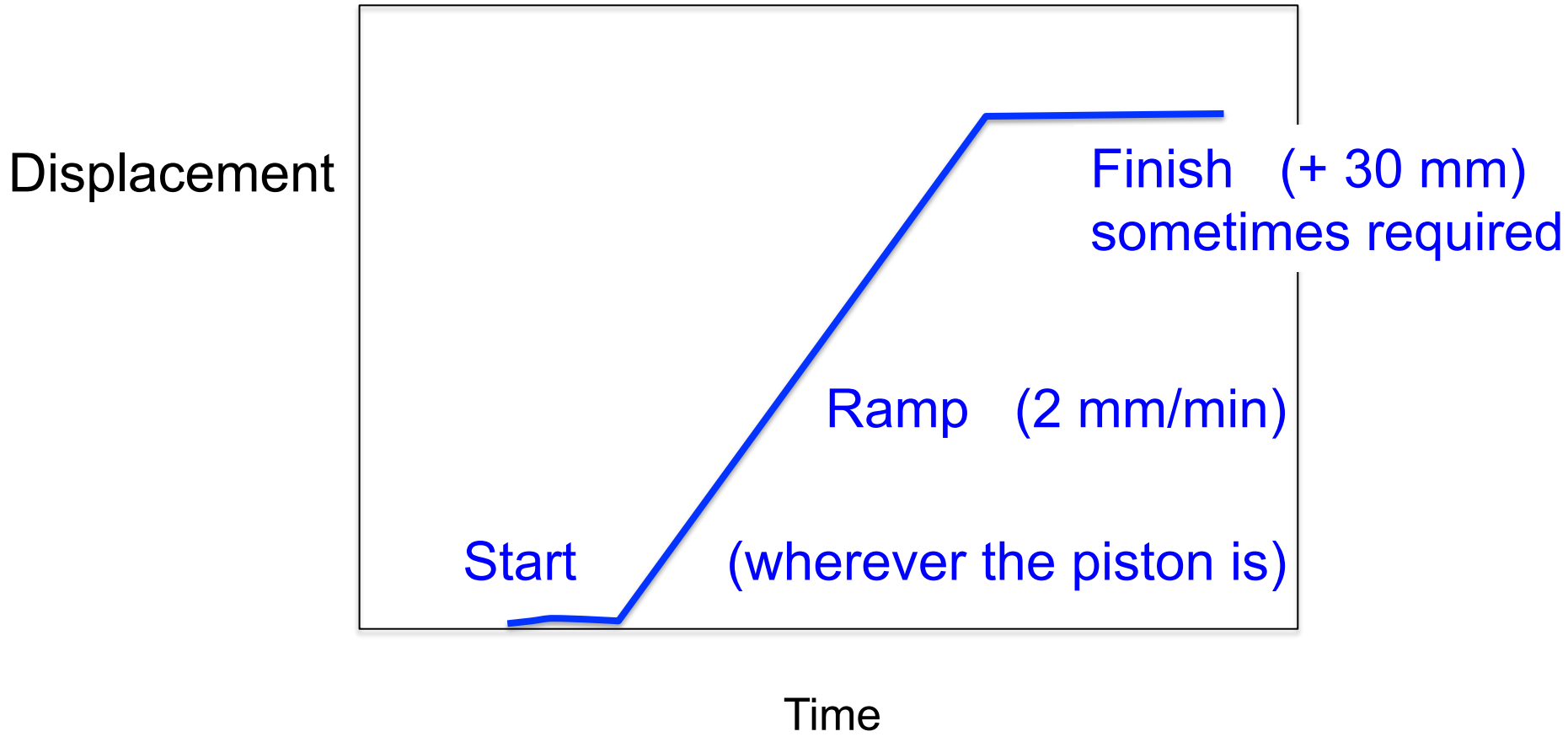
Displacement to failure: 5 mm*

Displacement rate: 2 mm /min



* *calculated based on 200 mm gauge length and displacement rate (need to measure it directly, if you need it accurately)*

Choose Loading Type (Ramp)



You need to set the parameters defining your loading type

Set Limits

Always set limits! They protect you, and the machine. Set limits by "feeling".

Failure load: 20 kN

Displacement to failure: 5 mm

Displacement rate: 2 mm /min

If the machine exceeds a limit the oil supply gets shut off, it stops.

Limit Load

Max: + 30 kN, Min: – 1 kN (about 3 tons and 100 kg

Limit displacements

Max: 40 mm, Min: - 5 mm

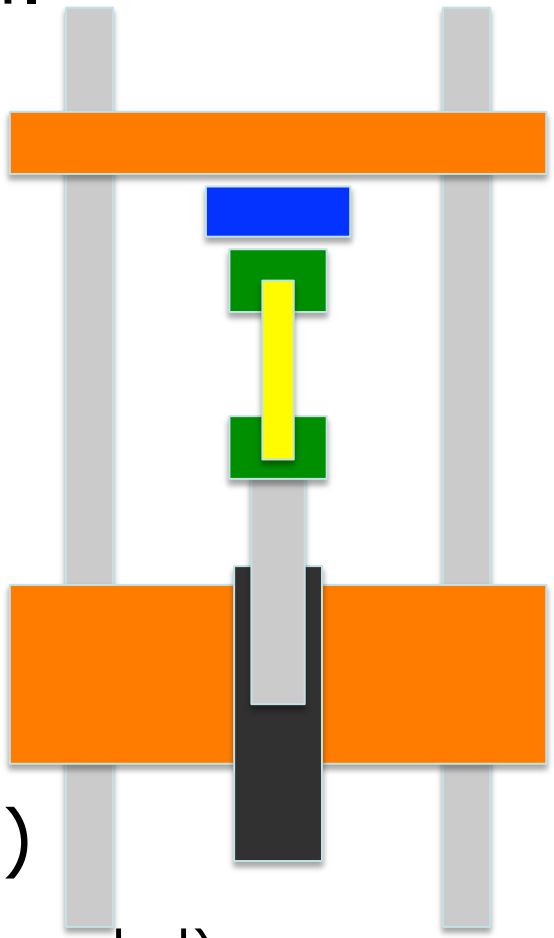
Always set limits within "machine limits"

Move piston to 0 position, before you set the limits.

Install Sample

Install Sample

- Move Piston to about 0 position.
- Release Crosshead and move Crosshead high enough that you can put the sample into the lower grip.
- Move Crosshead down and close upper grip.
- Lock Crosshead (do not forget!)
- (slight variations of this procedure may be needed)



Move Piston

- Make sure main pump is running
- Switch power on, can be a two step process
- Need to know how to move the piston
- Machine must be in displacement control
- Usually piston is moved by a little wheel or displacement coordinates are typed in (may make the piston jump).
- Move the piston slowly, but not too slowly

Move Crosshead

- Need to know the levers or valves to lock/ unlock and move the crosshead.
- Unlock the crosshead first.
- Do not try to move the cross head when it is locked.
- Lock the crosshead when you are done!
- If the sample does not want to fit, you may move the piston for fine adjustments – or repeat the whole procedure.

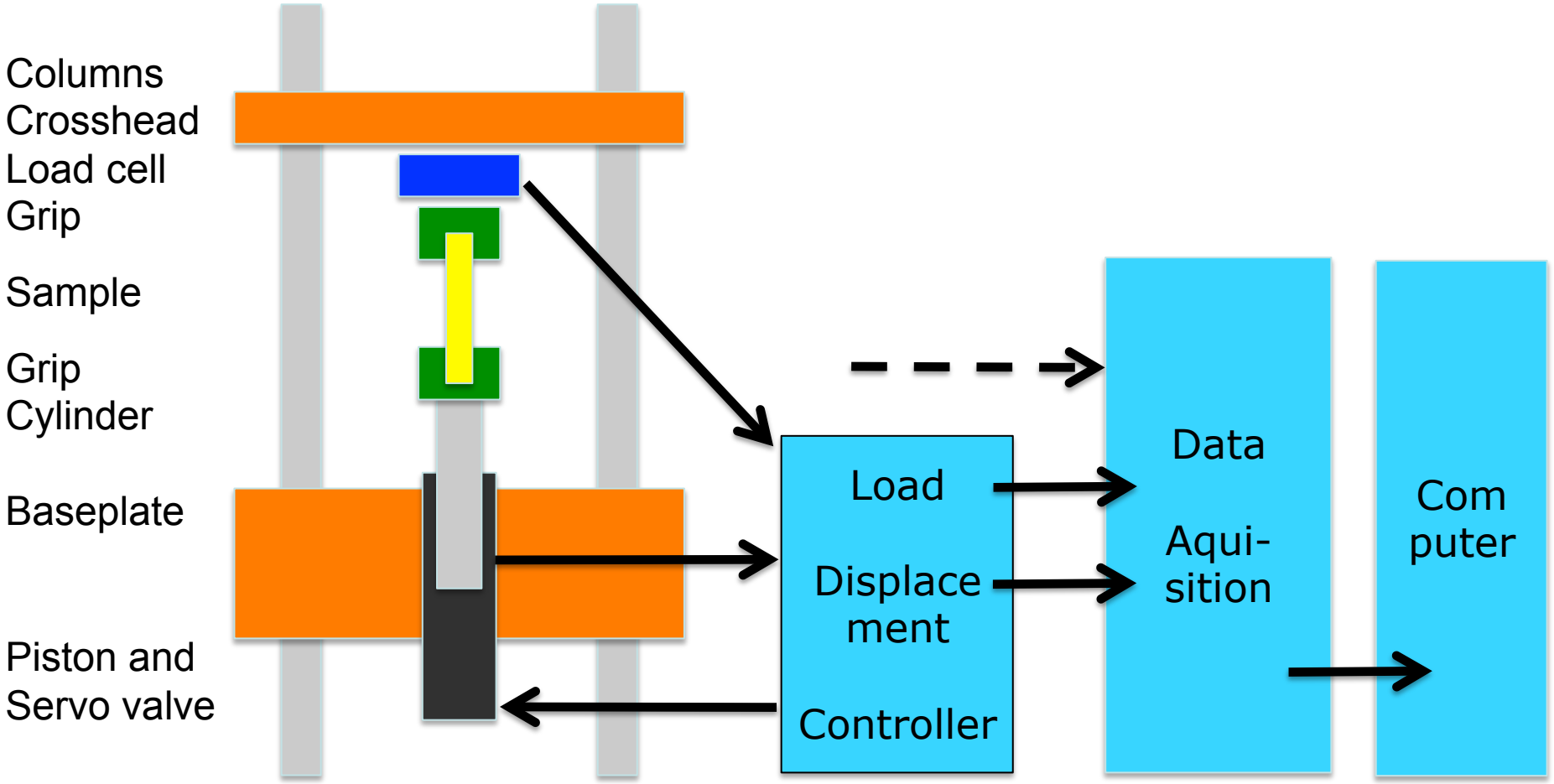
Closing Grips

- Learn how to open and tighten the grips.
- Use the right wedges for the thickness of the sample.
- Hydraulic grips: Too high pressure may crush the sample. Too low pressure → the sample may slip out.

  You may have to put tabs on the samples (beyond the scope of this introduction)
- Closing the second grip tends to put some load on the sample. You may want to record that!

Set Up Data Acquisition

Principle of a test machine



Data Acquisition System

- Load Cell and Displacement Signal are always connected to the Controller
- You want to also connect them to your data acquisition system.
- Output is usually +/- 10 V. Check!!!
- Tell your data acquisition system what the 10 V mean. RECORD that!
- Be aware when you want to start your acquisition. (When you close the grips? When you start the test?)
- Have a good routine to start the acquisition, otherwise you may run the test and forget to record it.
- You may want to add many more sensors and channels.
  - Make sure the data is synchronized to the same time.

Advise

- Record and store the raw data. Never touch them again!
- Copy the raw data and create your calculated data from the copy.
- If things go wrong, you can always go back to the old raw data.
- Keep a record of all calibration and conversion constants.
- MAKE BACKUPS
- Make your own folders to avoid conflicts with files from other users.
- Name your specimens and data files and folders in a “smart” way that you can easily identify them a few months later.

Internet - Virus

Our data acquisition computers and controllers are NOT connected to the internet and should NOT be connected.

Always follow current procedures on how to transfer data!

Extra Instrumentation

- You may want to measure more things than just load and displacement. This may lead to extra instrumentation such as strain gauges, optical fibers, Digital Image Correlation etc.
  - The principles of data acquisition remain the same, it just gets more complex.
- You may also want to test in different environments, requiring climate chambers around the specimen.
  - Testing principles remain the same, but you have to do a new safety evaluation.

Run the test

Ready to go?

Check that limits are set

Check that the proper wave form was selected

Check that all safety screens are in place

Check that nobody is behind the machine

Check that data acquisition is running

Press the RUN button

RUN button

Run - starts the selected waveform / program

Stop - Stops the machine, piston remains where it is (displacement control). Sample will be still loaded.

Run - press again and the machine continues.

Finish – machine goes back to 0 position. You usually do not want to use that.

Typical test sequence

Press run butten

Look at specimen (but do not get too close! – very tempting sometimes)

Watch data on screen of acquisition system

Bang – Sample breaks

Press Stop Button

Check that load is about 0, if not maybe continue the test (press run again)

If really broken, Stop data acquisition

Take out specimen (make sure load is 0, otherwise move piston→ see exceeding limits.

Switch off machine or start new test & Clean up!

Exceeding limits

When limits are exceeded the machine stops

Since pressure is removed the load tends to go to about 0, check that this is the case

Switch to displacement control, if you are not in that mode already.

You need to remove the violated limits and move the piston back inside the limits. Reset the limits afterwards.

If you are uncertain, get help!

Running test in load control

What is the difference?

In displacement control, the controller calculates the set value (displacement vs. time) reads the actual displacement. If there is a discrepancy the servo valve is opened to move the piston to the set value.

In load control the controller does the same, but compares set and actual load.

Behavior under failure

Displacement control:

Sample fails, load drops close to 0, piston keeps moving slowly since the controller does not know that the load dropped.

Failure Load Control

Sample fails, load drops close to 0

Controller sees large difference between set load and actual load, opens servo valve all the way.

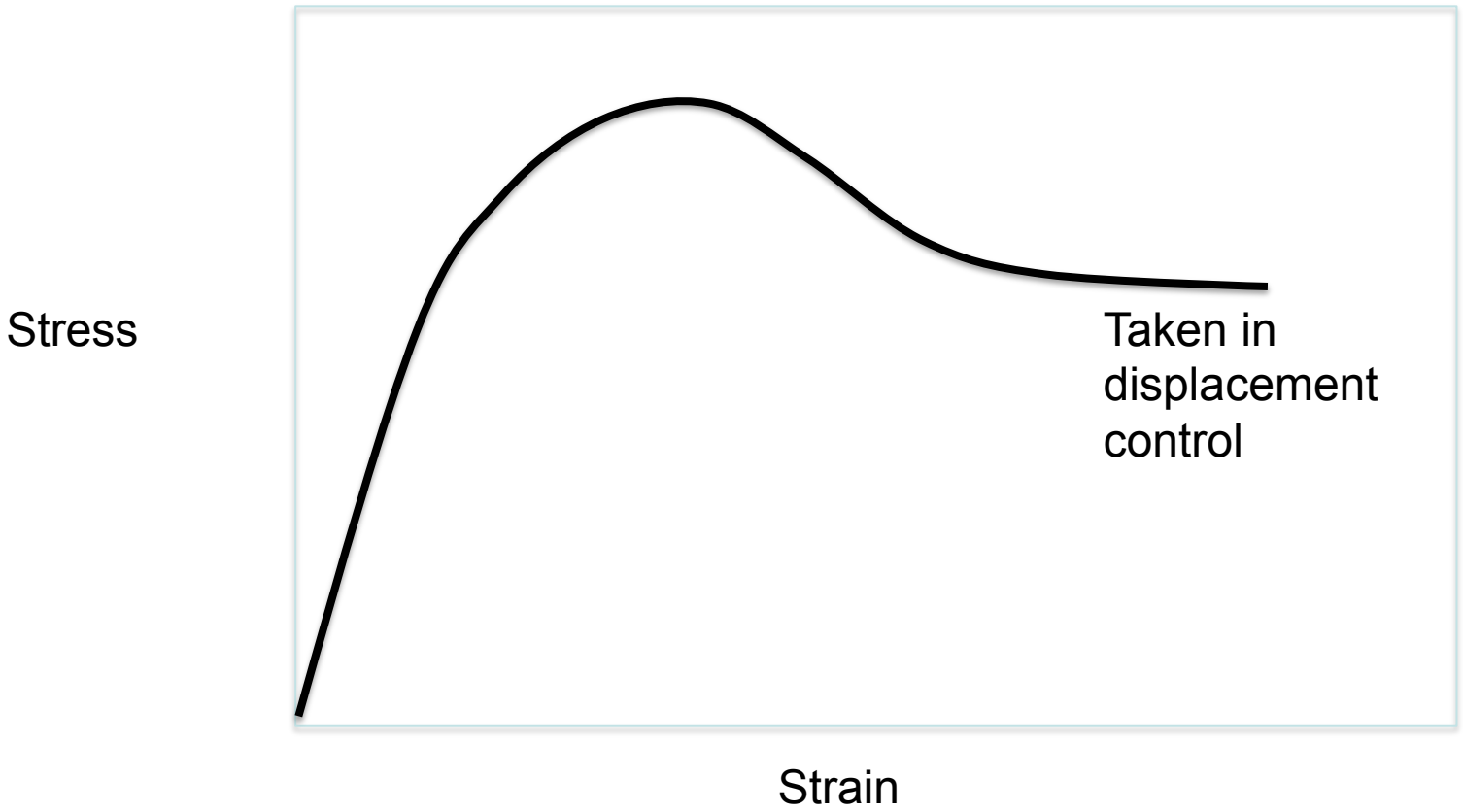
Piston goes full speed to “increase” the load.

Only the limit setting stops the piston.

Without set limit the machine may get seriously damaged.

Displacement control is more stable ....

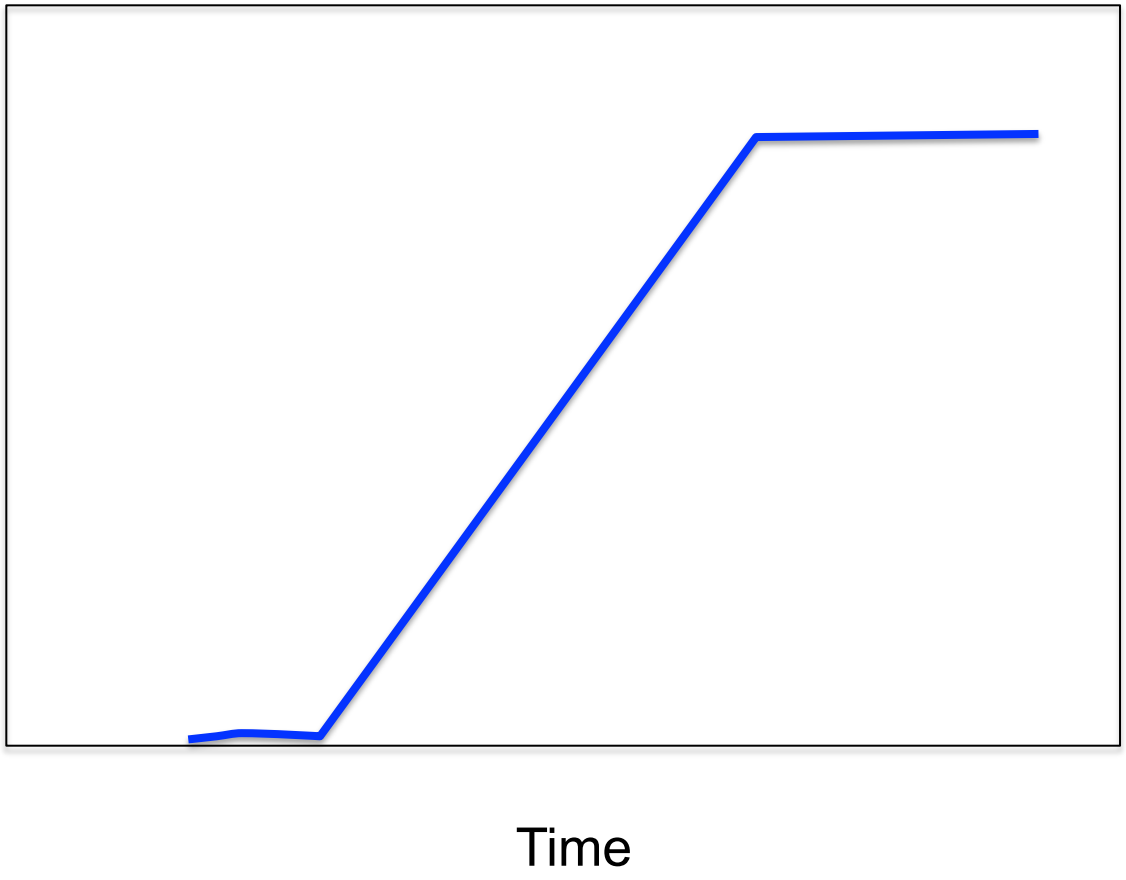
Stress-Strain Curve



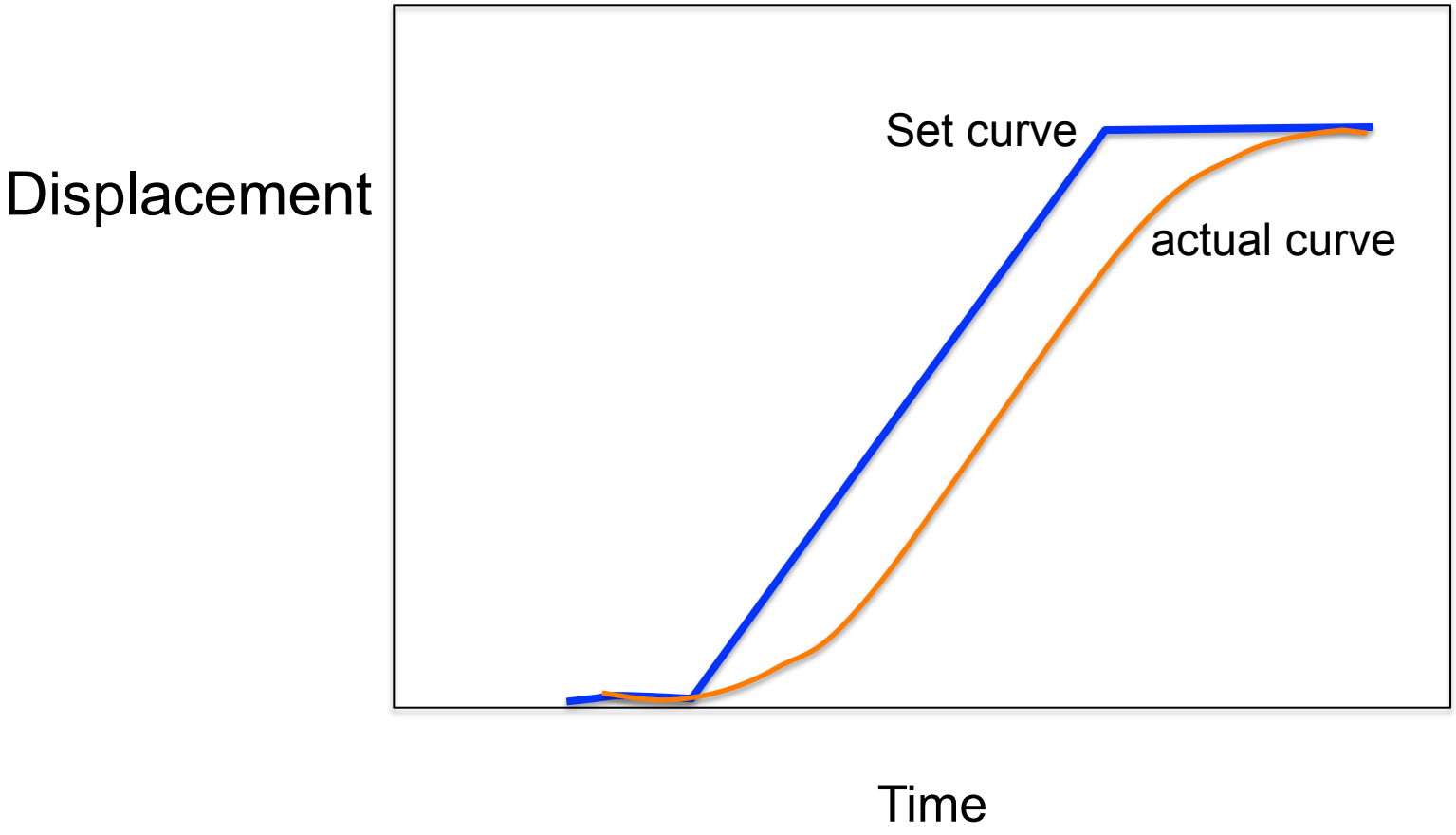
How would the curve look if it had been measured in load control?

What they do not talk about....

Set Curve



Control of the feedback loop



Controlling the gain

In old machines you had to set a right gain value to minimize the difference between set and actual curve.

Modern machines tend to set the gain automatically in the background.

For most common materials and tests the default gain settings are fine.

For advanced work you should check set and actual value – find out how to take out both curves.

Possibly you need to set the gain yourself.

Mostly important for fatigue testing.

Fatigue Testing

Fatigue Test - Example

Unidirectional composite in fiber direction

Expected number of cycles to failure 10^5

Sinusodial cycling between 20 and 200 MPa

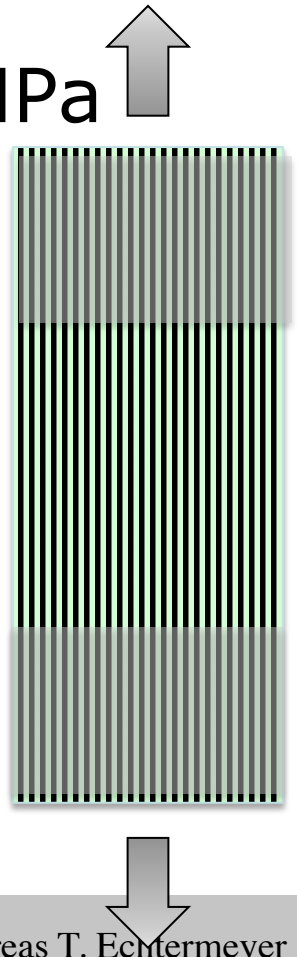
Dimensions 300(200)x25x2 mm

Frequency 4 Hz

Load between 1 and 10 kN

Displacement up to about 2.5 mm

Test duration 7 hours (can be easily 70)



Setup Fatigue Test

About the same as for the static test

Select Waveform: Sinus

Watch out what you have to define and set:

Minimum and maximum load

Mean and Amplitude (or Range)

Starting point at mean or minimum?

Etc.

(blue is the most common format)

Run

Most fatigue testing is done in load control. Why?

Bring piston to mean

Set limits!

Press run

Machine runs by itself and counts the number of cycles

When the sample fails the machine will exceed a limit and stop.

You can read the number of cycles to failure from the counter. Know where the counter is and set it to 0 before you start the test.

Data monitoring

- Good to monitor vs. time:
  - Set load
  - Actual load (Gain control.....)
  - Displacement
- Other measurements and data handling is beyond the scope of this introduction, but make sure the data is properly synchronized to the same time.
- Gain control is more important for fatigue than for static testing, because the sample can change its apparent stiffness (crack growth, yielding ...)

Possible long-term problems

Interference from other tests. All machines get oil from the same hydraulic circuit. A shock from one test, can influence/destroy another test → talk to each other!

Power failure: Happens once in a while. Pump stops, machine stops, computer stops (lab-top is better). Try to minimize the consequences of these accidents.

last but not least

CALIBRATION
and
ALLIGNEMENT

Formal Aspects

Load cell, strain gauges etc. should have calibration certificates.

Testing for safety critical applications requires frequent renewal of the certificates (accredited lab).

But the potential problems for us tend to be at other places.

Load Cells

The load cell can get damaged from overloading or misaligned machine/loading path.
Be CAREFULL with the load cells, especially cells for small loads!

You as a user cannot do much about ensuring the accuracy of the load cell, but you can check the machine by testing a known material once in a while.

Check what voltage corresponds to what load.

Alignment

You cannot check the alignment of the machine, but it should be done by the lab once in a while.

But you should try to align your sample as good as possible!

Misalignment may damage load cell and piston.

Misalignment obscures your data.

Strain Measurements

Displacement measurements of the piston tend to be accurate. It can easily be checked with pin calipers. But displacement should generally not be used to calculate strain, because samples can slip in the grips and due to slack in in connections.

Extensiometers should be calibrated before each use.

Strain Gauges

The most common way to measure strain.

Strain gauges are calibrated and come with gauge factors in the package.

The gauge factor needs to be written into the data acquisition program. Do that properly! Has been done wrong many times...

Data Acquisition System

You have to put in calibration and conversion constants.

Typing in wrong numbers can create big problems and confusion later.

Check the numbers carefully

Record and keep the constants, to make it traceable.

READY to TEST?

Next Steps

You have gotten an overview and some ideas how the test machines work.

You should next try a simple test on a real machine together with an expert.

Then you should be ready to run your own tests. But each time you run a new test do it initially together with an expert.

Do not forget, you also need a signed risk assessment for each type of test.

Confirmation

I have read and understood the slides of the presentation “Introduction to Using a Mechanical Test Machine”
Version: 2021/01/25

Name and date

Please return signed pdf of the entire presentation to the fatigue lab.