Guidance – Fretting Rig Design

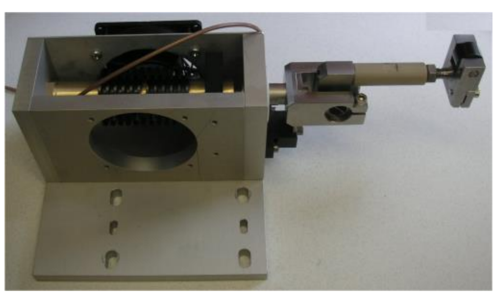
The design of fretting test machines presents a number of special problems in particular in respect of precise control of amplitude and mid-stoke position. Designs for high temperature applications or for hostile environments present challenges in respect of material selection. High frequency applications require considerable care in the design and selection of instrumentation and signal conditioning in order to avoid frequency response and phase angle errors.

Methods of Actuation

Electro-mechanical Actuation

- Electro-mechanical systems of actuation (a motor driven mechanism) can provide a simple and perhaps nominally cost-effective means of stroke actuation. However, such systems suffer from a number of serious limitations.
- It is very hard to devise a system that allows control and adjustment of the stroke length while the machine is running. It is very hard to devise a system that will allow precise adjustment of the mid-stroke position to compensate for thermal expansion while the machine is running.
- Mechanical drive systems, involving bearings, lack the necessary stiffness and are subject to fretting and fatigue failure.

Piezo Actuation



- Piezo actuation can provide a cost-effective means of actuation for low load applications, with the benefit that the inertia of moving components is very low, hence minimizing out of balance forces and the requirement for a high mass machine.

- Actuators are readily available with stroke lengths in the fretting range and with driving forces of up to 300 N (in tension) and 1500 N (in compression).
- There are a number of limitations that should be considered
- The stroke of a piezo actuator is directly proportional to applied voltage.
- The achievable frequency is a function both of the mechanical natural frequency of the actuator and associated tooling and the electronic frequency response of the actuator and associated power amplifier. Typical performance for an actuator with a 140 micron maximum stroke is as follows:

At 100 Hz	Maximum stroke	40 microns (+/- 20 microns)
At 50 Hz	Maximum stroke	80 microns (+/- 40 microns)
At 20 Hz	Maximum stroke	140 microns (+/- 70 microns)

- The fatigue life of a piezo actuator is directly related to the total applied current.

  For the 140 micron actuator, we have the following:

At 40 microns stroke	10^9 cycles
At 80 microns stroke	5×10^8 cycles
At 140 microns stroke	2×10^6 cycles

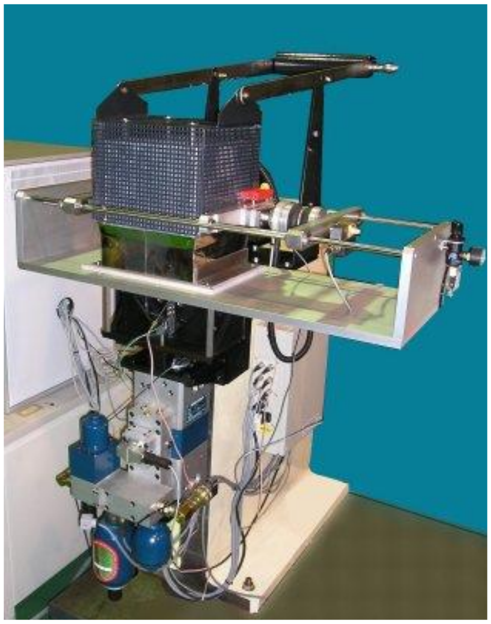
Electro-magnetic Oscillator

- Electro-magnetic oscillators have been used, but it is questionable whether this has ever resulted in entirely satisfactory results. The key problem with this type of a device is that it is a force as opposed to a displacement generator. The resistance to motion of the machine in pure sliding is of course the friction in the test contact, and in fretting, a combination of friction and elastic deformation.
- Because the resisting force changes as the test progresses, the loop gain of the system varies thus altering the system response. Even though the

actuator will be operated with positional feedback, the positional control loop is still in cascade with the primary force loop. Controlling amplitude and stroke mid position is extremely difficult.

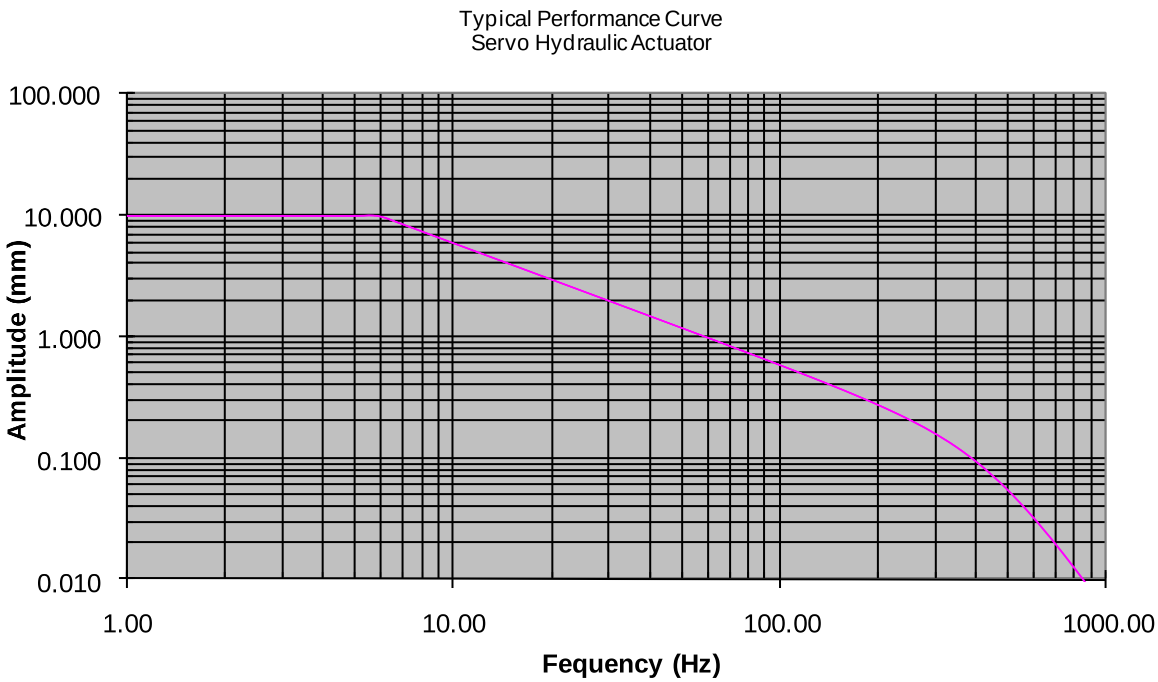
- These types of device are only satisfactory if an actuator with a capacity far in excess of the anticipated resisting force is used. Such large actuators invariably have high mass moving parts with the potential to give rise to problems with parasitic vibrations.

Servo Hydraulic Actuation



- Servo hydraulic actuators provide very stiff driving systems. Short stroke actuators, can provide precise control of displacement and mid-stroke position, over a wide range of frequencies.

- With a high quality short stroke (say 20 mm maximum stroke) servo hydraulic actuator and appropriate control system, it is possible to achieve precise and continuously variable control of stroke length in the range +/- 1 micron to 10 mm with a control resolution of +/-0.2 microns and frequencies up to 200 Hz. The actuator should of course be fitted with hydrostatic bearings to avoid fretting.

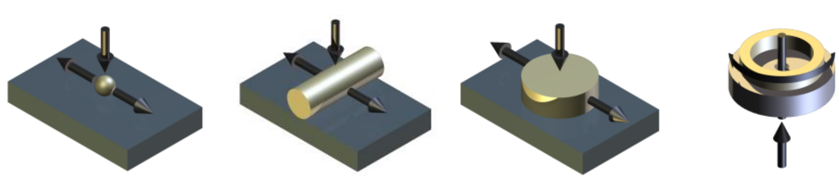


Control System Requirements

There is one caveat with all designs of fretting test machine. At fretting stroke lengths, it is normal to use a capacitance probe, LVDT or similar displacement-measuring device mounted on the fixed specimen carrier and targeted on the reciprocating specimen carrier, measuring and controlling the displacement of the moving sample with respect to the fixed sample. It is important that the control system not only controls the amplitude of oscillation but it must also have the capability to control the mid-stroke or mean position of the motion. Without this, the moving specimen's mean position can change as thermal expansion or other causes of drift take place.

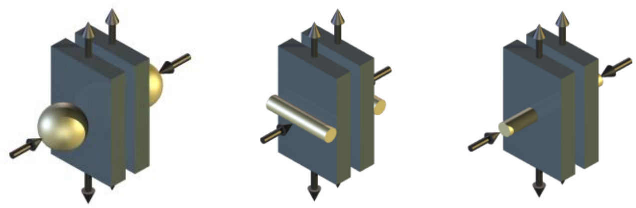
Specimen Configurations

Conventional specimen configurations worth considering include the following:

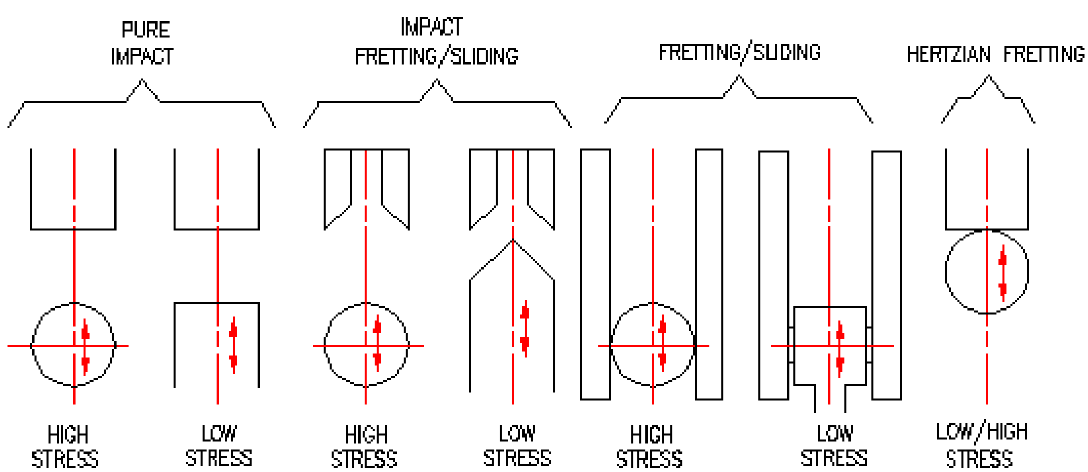


With linear reciprocation, it is not particularly difficult to ensure that the specimen contact area and line of action of any driving mechanism are coaxial, however, it is not easy with these configurations to avoid, at high loads, undesirable resonance problems associated with flexing of the specimen arm.

This particular problem can be overcome by adopting a design in which a single moving specimen is reciprocated in contact with two fixed test surfaces. Providing the friction coefficients on both test surfaces are approximately equal, there is no net moment on the moving specimen.



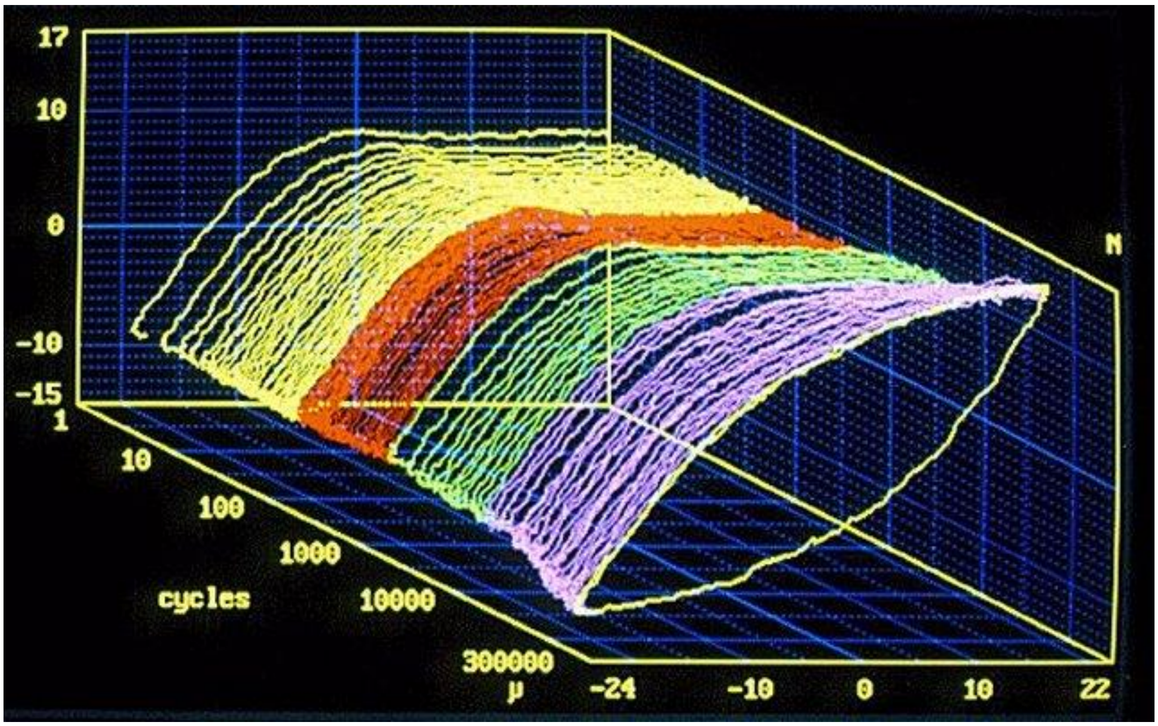
Minor modifications to this tooling arrangement can provide the capability for a number of other, in some cases potential more interesting, test geometries.

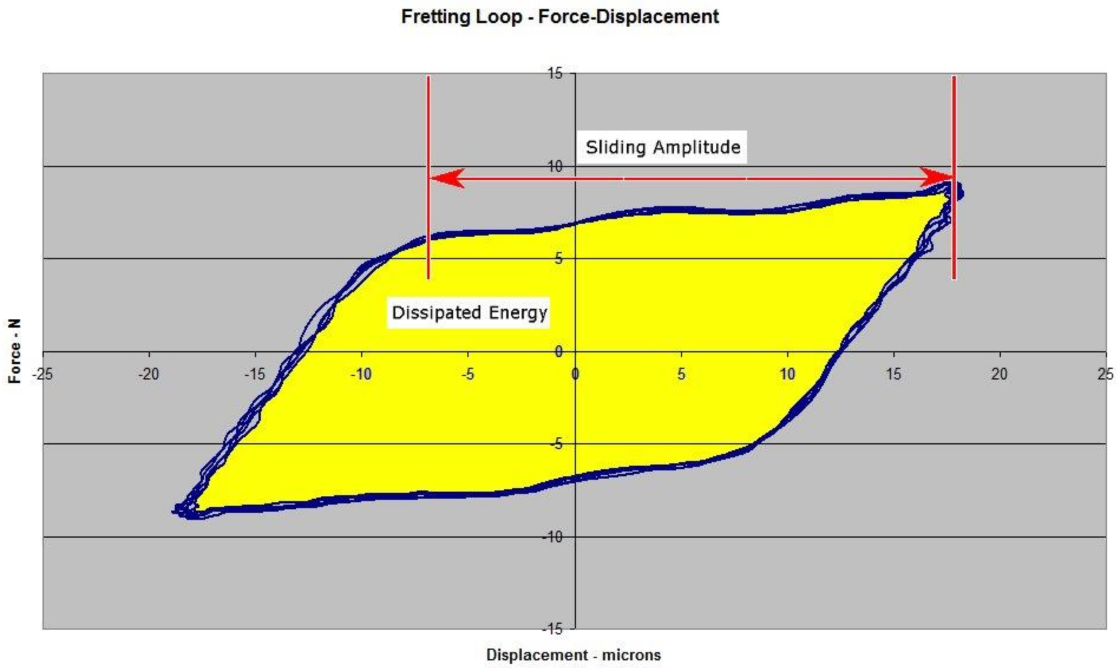


Output Data

The most commonly used real time output for fretting tests is the force displacement curve. The transition from a hysteresis type curve to a trapezoidal curve is usually identified as the point of transition between combined elastic deformation and micro-slip to gross slip, the latter condition being typically associated with the generation of third bodies (oxide debris) in the contact.

A number of researchers have presented data in which filtering techniques are used to “clean up” unsatisfactory force displacement curves. It is difficult not to treat “corrected” post-processed data with anything other than suspicion. High quality data, which records what is happening in the tribological contact, free of machine vibrations and signal processing errors, should be the target and is readily achievable with the right engineering design.





Note that the limitations to performance, in terms of reciprocating frequency, are entirely dependent on the frequency response of the measuring system and not on the performance of the actuator. For further information on frequency response, filtering and sampling rate, see:

Tutorial - Friction Force Measurement in Reciprocating Tribometers

Conclusion

- The actuator should provide precision control of displacement and a means of maintaining the mid-stroke position of the relative motion.
- Until the transfer function of the measuring system has been analyzed, the validity of force-displacement data may be suspect.