Load testing

Uncertainty of measurement of load testers

Definitions

Uncertainty of measurement is an estimator describing the range of measured values inside of which the true value may be expected above a specified confidence level - e.g. 95 %; i.e. it is an expression of the accuracy of the measurement taken. Uncertainty of measurement is made up of two components: systematic error S and random error R.

The squares of both these components are added together, because when calibrating a load tester only the maximum deviation in a test is taken as error for calculating uncertainty of measurement. As the maximum values of these errors will never occur in a test, we take their squares and add them together. Linear addition would make the result too high.
Systematic errors S of a load tester may be found by using a measurement standards (= master) or in comparison with a multitude of other load testers (see The HAUSSERMANN inter-laboratory test).

If the causes of these errors are known, they may be compensated for by calibrating the machine. Random errors R, however, cannot be influenced by calibration. If they are too large, the tester may not be capable of testing springs.
The uncertainty of measurement of a load tester is determined by the uncertainty of measurement of the load measuring unit and the uncertainty of measurement of the length measuring unit. In both cases it consists of the following components:

q = error of output value related to the true value
b = repeatability range of values related to their means
a = resolution of reading
s = hysteresis error related to the mean
f = null drift as residual reading after unloading to zero and related to the value at the end of the measuring range.

Assuming that the deviation of b and a is symmetric in relation to their mean, we can take only one half of them, i.e. a/2 and b/2. Elements b and f are considered to be random errors, the rest systematic errors.

Detecting uncertainty of measurement

The uncertainty of measurement of loads (U_{Load})

The elements of U_{Load} are related figures and given in (%).

1. Error of output value q
   At different loads in the load range the differences between the machine readings and the master are related to the "true" value of the master. The greatest value is to be used. Machines with only 1 load cell will most likely contain additional errors with loads off-center. As this may happen in practice by deviations parallelism within a larger spring, we recommend this error be eliminated by using testers with 3 load cells arranged on a pitch dia at 120 degrees apart.

2. Repeatability b
   The load given by the master should be checked 10 times. The difference between the biggest and the smallest readings is related to the mean of all 10 readings. This test should be carried out during compression only, as we assume the same error during release motion. All other elements are mentioned above.

The uncertainty of measurements of heights (U_{Height})

The error of height measurement affects the test result is related to the spring rate of the sample. This error therefore plays an essential role in measuring stiff springs.
The elastic distortion of the entire test set-up is one of the main reasons for height error. It is hence important that U_{Height} be determined under load. The elements of U_{Height} are measured in mm or in.

1. The error of output value q:

The error of output value q is caused by:

- elasticity of machine. If compensated for, it shows the effectiveness of the compensation;
- accuracy of the height measuring sensor;
- linearity of the transfer elements.

Before measuring q, the parallelism and flatness of the two test platens should be checked with a pressure piece in center and than, e.g., 150 mm off-center under a load which is 12 % of rated load. Certain limits must not be exceeded (for reference, see The HAUSSERMANN-Load Tester).

When measuring q, we recommend the use of a probing ring as a reference standard. The advantages are:

- no friction between the sample and the test platens or fixtures other than dia-phragm springs;
- high spring rate (40kN/mm for instance);
- height of the probing ring allows the insertion of a dial indicator between the test platens passing through the deflection range of the probing ring. The greatest deviation between the indicator and the output value of the height is taken as q.

2. The range b:
The test set-up as described above is used for measuring b. The machine deflects the probing ring 10 times to a constant load. The greatest deviation between the readings of the indicator and the machine is taken as b.

3. Resolution of reading a:
The resolution of the measuring unit and the transducer (increment) may be taken from the machine manual. The increments should not be confused with the digits.

4. Hysteresis error s:
Diaphragm spring load is often measured during downstroke and/or upstroke. It is therefore important to have information about the hysteresis error of load tests. With the test set-up as described above we can measure hysteresis as the greatest deviation between the readings on the indicator and the machine display at the same heights during the up and down strokes.

5. Null drift f:
If the machine display shows values other than zero at the end of any of the ten cycles, the greatest value should be used.

6. Slew error:
Machines using the pass-through technique should show the same test results at different measuring speeds.

Total uncertainty of measurement U_{Total}

$U_{Total} = U_{Load} + U_{Height}$

Because of the dependence on spring rate, U_{Total} cannot be determined as a general value but only for specific cases. To do this, we must know the spring rate at the specific height and the relevant force. The following example shows how U_{Total} should be calculated:

The load tester features:
U_{Load} of ±0.5 % of the measuring value, and
U_{Height} of +0.006 mm
The spring in question has a spring rate C of 26 kN/mm at a height L of 6.75 mm.
The spring load F at this height L is 23.250 +2.325 N.
U_{Load} = 23.250 N x 0.005 = 116.25 N
U_{Height} = 26kN/mm x 0.006 mm = 156 N
U_{Total} = +272.25 N

The accuracy of a load tester in relation to the load

Tolerance limits
The acceptable uncertainty of measurement of the load tester depends on the specified load tolerance.
A measuring device is generally expected to have an accuracy that is at least 5 times greater than the specified tolerance T, i.e.:
$U_{Total} < 0.2 \times T$
Taking the above example,
T = +2,325 N
0,2 x T = + 465 N
U_{Total} = +272 N <465 N
i.e. the load tester is capable of measuring this spring.
The tolerance limits should be adjusted on either side by the full value of U_{Total} to ensure that no "true" measured value falls outside the specified limits. An actual example can be found in the chapter The HAUSSERMANN-Spring Load Tester.