SIGMA
TESTING SYSTEM

Creep System Hot Stepped Loading Information

How is plastic strain during loaded determined in a creep test?

Plastic strain during loading is the non-elastic deformation of the test sample that can occur during specimen loading in a creep test. Plastic strain during loading can be measured by a process called hot stepped loading, when the test is started or by measuring the specimen's elongation at the end of test and subtracting the creep value to yield the plastic deformation. The end of test method is rarely used because it is not very accurate due to many factors. The ATS WinCCS creep system fully implements hot stepped loading, instead of waiting for the end of the test for the following reasons: 1. Hot stepped loading has a distinct advantage because the plastic deformation is known at the beginning of the test instead of the end. In production work the test termination point and pass / fail requirements are based on knowing the plastic strain during loading at the start of the test. In experimental work, the test may be terminated early due to excessive plastic deformation. 2. For either type of testing if the specimen ruptures it is very difficult to determine what the actual plastic deformation during loading of the specimen was. 3. Since both methods rely on the extensometer system used to measure the creep, they both have the same errors.

What is a creep hot stepped load?

A creep hot step load is a procedure that is performed to load a creep specimen to determine the plastic strain at the start, instead of the end test. The procedure consists of applying weights of known values to the specimen and measuring the resultant strain at each step. The data can then be mathematically processed to determine the plastic elongation and / or strain during loading, modulus, starting position of the extensometer, and a relative check on the functioning of the extensometer itself.

The procedure is as follows:

Once the specimen has reached temperature and soaked the specified amount of time, zero the extensometer close to its minimum calibrated extension. Record the extensometer reading and the stress applied of the pre-load weights. Note: It is very important to apply a pre-load to the sample because without any pre-load the extensometer errors can be significant.

Apply at least five additional applications of load up to the required specimen load, and record the extensometer reading and the total stress applied at that step.

When the loading is complete, perform a least square fit on the extensometer and stress data that was recorded. Only use the points from pre-load up to 80% of the full stress value applied. The 80% of total load is an assumption that on a normal creep test there should be no plastic deformation of the specimen below that load.

The resultant slope from the least square fit is the modulus of the specimen in in / lbs., less the frames arm ratio. It can be converted to conventional units of PSI by the following formula.

Modulus (PSI) = Arm Ratio * Gage Length / (Specimen Area * Loading Slope)

The intercept from the least square fit is used to correct the extensometer data. Since the first data point starts at pre-load, the actual zero point in inches of the extensometer is not known. The intercept is the offset from zero for the displacement data and is subtracted from each extensometer reading to correct it to zero.

The plastic extension may now be computed as the difference between the predicted extension obtained via the loading slope and the actual final extension as follows.

Predicted Extension = Total Pan Load * Loading Slope

Plastic Extension During Loading = Final Displacement - Predicted Extension

Note: The ATS WinCCS creep system will report negative values of plastic extension on the Hot Load Report but will use zero for the total plastic strain data. This is because a negative value is attributed to binding or alignment problems.

Example

Specimen Area: 0.0494 in^2

Gage Length: 1.494 in.

Arm Ratio: 20 to 1

Below is the raw data measured by the system during a hot stepped load. Data

Load (lbs.)	*Extensometer Reading (In.)*
18.2	0.049823
27.6	0.050136
41.1	0.050710
50.5	0.051234
60.9	0.051632
70.7	0.052087
81.7	0.052645
91.7	0.053153
102.3	0.053728
112.3	0.054271
122.3	0.054860
131.0	0.055349
146.1	0.056448

131.1 lbs. is greater than or equal to 80% of the total load. So, a least squares fit of the data from 18.2 to 122.3 lbs. is performed. The resultant data is shown below.

Loading Slope: 0.000048494 in. / lb.

Intercept: 0.048772 in.

Correlation Factor: 0.998356

Note: The ATS WinCCS creep software will display any correlation factor with a value below 0.9 in red on the hot loading report. The correlation factor is a measurement of how well the data correlates to a straight line. The closer the correlation factor is to one, the better the data fits a straight line. If the correlation factor is below 0.9 then the entire hot load data set should be questioned. Bad load data is usually the result of extensometer binding, specimen yielding below 80% of final load, specimen preparation, improper weight application or extremely light loads.

From the loading slope the modulus can be computed:

Modulus of Elasticity: 12469867 PSI

Using the intercept, which is the offset from zero of the first point the data is corrected to reflect where the extensometer would have been is zeroed at zero load.

Load (lbs.)	***Extensometer Reading (in.)***	***Intercept (in.)***	***Corrected Reading (in.)***
18.2	0.049823	-0.048772	= 0.001051
27.6	0.050136	-0.048772	= 0.001364
41.1	0.050710	-0.048772	= 0.001938
50.5	0.051234	-0.048772	= 0.002462
60.9	0.051632	-0.048772	= 0.002860
70.7	0.052087	-0.048772	= 0.003315
81.7	0.052645	-0.048772	= 0.003873
91.7	0.053153	-0.048772	= 0.004381
102.3	0.053728	-0.048772	= 0.004956
112.3	0.054271	-0.048772	= 0.005499
122.3	0.054860	-0.048772	= 0.006088
131.0	0.055349	-0.048772	= 0.006577
146.1	0.056448	-0.048772	= 0.007676

Using the loading slope the predicted extension of the specimen can be computed.

Predicted Extension = 0.00004849 in. / lb. * 146.1 lb. = 0.007085 in.

The final extension value for the hot load is 0.007676 in., which is greater than the predicted extension. Therefore, there was plastic deformation of the specimen during loading. The value is simply the final extension value less the predicted value.

Plastic Extension = 0.007676 in. – 0.007085 in. = 0.000591 in.

How does the Weight Based Auto Load function work?

The WinCCS Weight Based Auto Load function is an automated method of a hot stepped load. This option is typically used for very long-term creep tests where the user prefers fixed weights as the load but does not want operator involvement during the hot stepped loading process. In this variant, the system has an uncalibrated load cell in the load train to sense the load and uses the draw head or elevator motor to step the load by running the motor for timed steps. In between each step the system delays and then measures the value of the extensometers and the load cell and saves the values. Once the system detects no further increases in load it assumes that the weight pan is hanging and makes a final extensometer and load cell measurement. The loading data contains two known load points, the first being the preload point and the second is the total load point. Using these two measured points the system computes the slope and offset of the load cell and then converts the previously stored load cell voltage measurements into actual load values. This corrected data is then used by the procedure explained above to compute the plastic and predicted extension, modulus and creep starting displacement. Since this procedure only relies on the linearity of the load cell, and not its actual zero of offset it is very accurate method of determining these values without operator involvement.