

C R E E P

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LAB REPORT

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INTRODUCTION

Creep is a condition where a material will undergo progressive plastic deformation under constant load or stress. In most metals, this behavior is only present at elevated temperatures, but a few soft metals like tin and lead will experience creep at room temperatures. This experiment will explore the creep behavior of lead.

In many applications, mostly at elevated temperatures, creep can be a primary design consideration. Therefore, a thorough understanding of the creep behavior of a material is essential. The following relationship defines steady state creep in terms of stress, temperature and material dependent constants:

$$\frac{d\varepsilon}{dt} = C_0 \times \sigma^n \times e^{\left(-\frac{Q}{RT}\right)} \quad (1)$$

where:

C_0 , Q and n are material dependent constants

R = the gas constant

σ = stress & T = temp (in K)

In this experiment we will deform 3 samples of lead using different loads and measure the deformation versus time. From this information we will be able to isolate the variable 'n' in the equation above. With a few other simple tests, the remainder of the constants can be easily isolated giving a good understanding of the material's behavior in the steady state creep phase.

PROCEDURE

This experiment will determine the creep behavior of lead under constant load. It will be conducted three times with a new lead specimen, and in each subsequent trial the load will increase. The length of the specimen is measured every 15 seconds until either the specimen breaks or ten minutes elapse. The elongation of the lead specimen is measure by a dial test indicator (DTI).

MATERIALS NEEDED FOR THIS LAB:

1. Stop Watch;
2. Creep Machine (Sm 106 Mk II machine);
3. 3 Lead Specimens;
4. 3 Masses (0.65kg, 0.75kg,0.85kg)

INITIAL MEASUREMENTS:

1. Measure the length of the specimen, beginning where groove on the specimen starts.
2. Measure the width and the thickness

3. The Force that will be applied to the specimen is found by:

$$F = g(2.96 + 8m) \tag{2}$$

where: m = mass applied g = force of gravity (9.8m/s^2)

4. The constant shear stress that will be applied to the specimen is found by:

$$\sigma = \frac{F}{A} \tag{3}$$

CONDUCTING THE EXPERIMENT:

1. Put the first load on the creep machine
2. Gently place the first lead specimen in the creep machine. Time starts as soon as the load is applied to the specimen.
3. Every 15 seconds the length of the lead specimen is recorded from the DTI.
4. This is repeated every 15 seconds until the specimen breaks or the time limit of 10 minutes is reached.
5. Put the second load on the creep machine
6. Repeat steps 2 – 4.
7. Put the third load on the creep machine
8. Repeat steps 2 – 4

RESULTS

The following are graphs of each trial. Each one shows the strain behavior with respect to time under constant stress.

Figure 1 - Sample 1 (0.6kg load)

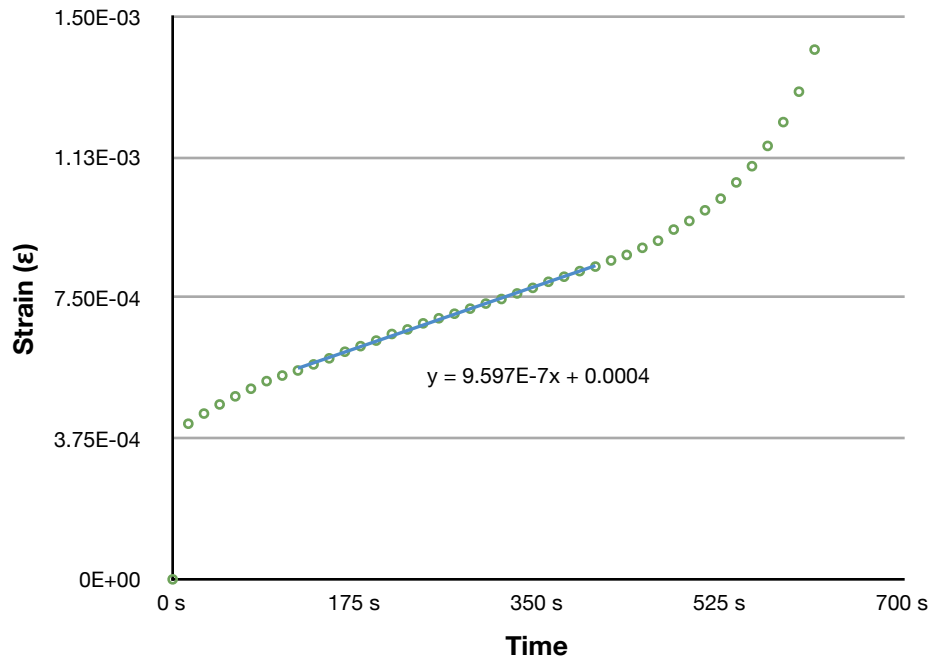


Figure 2 - Sample 2 (0.7kg load)

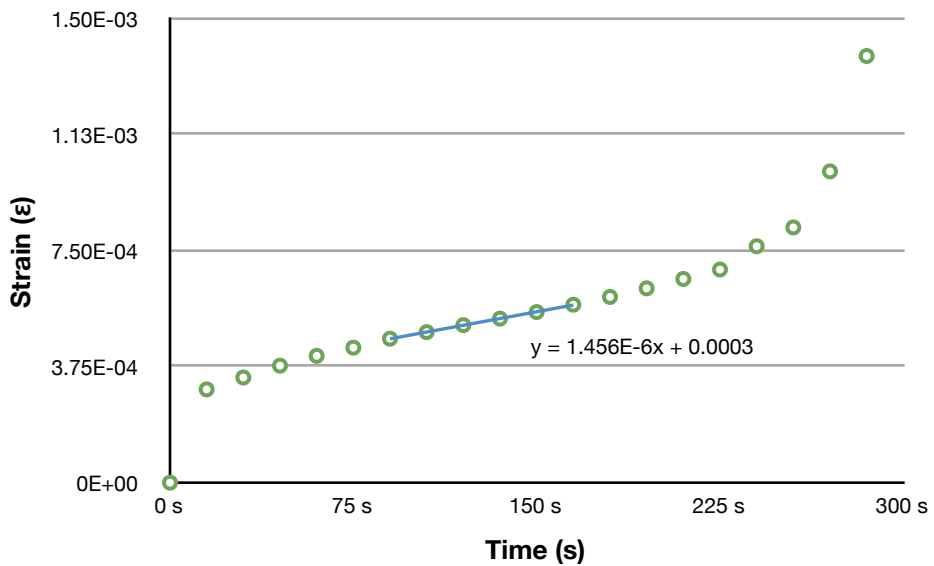
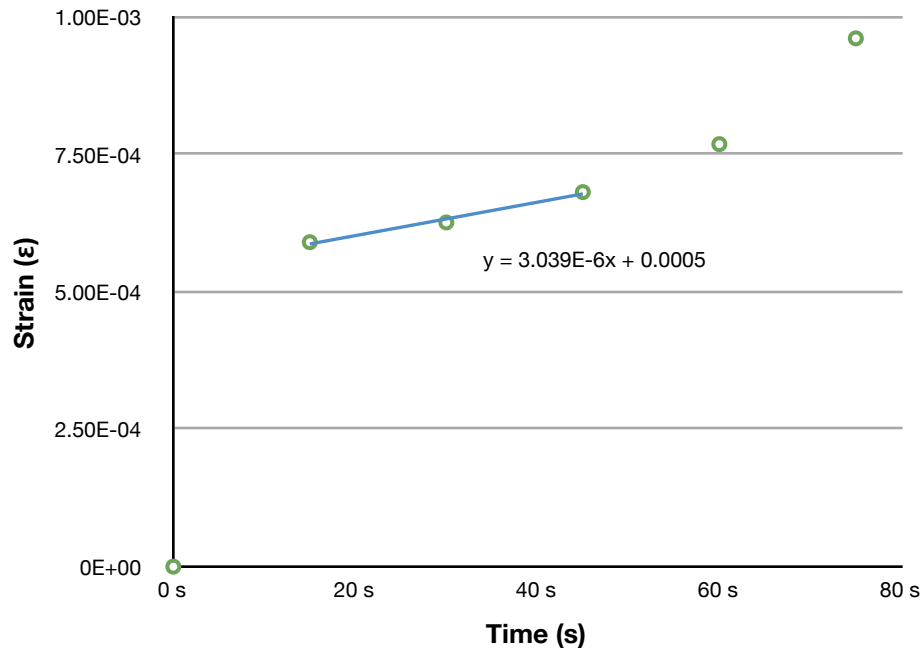


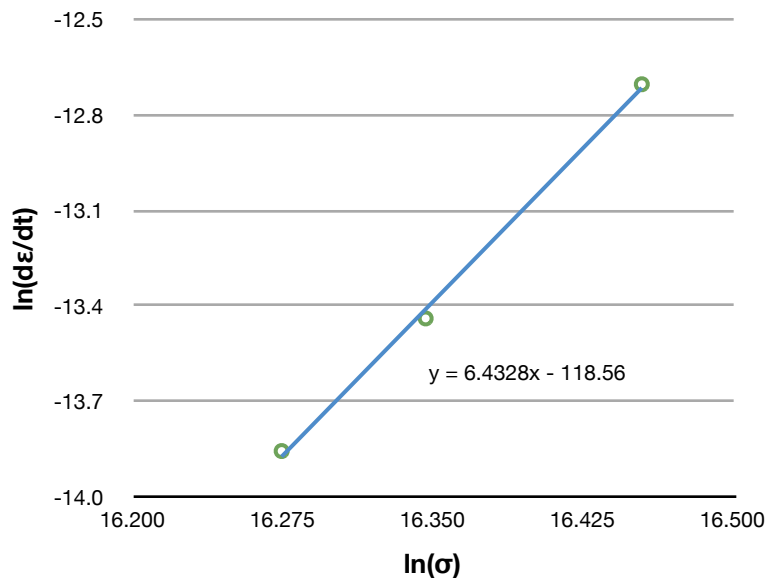
Figure 3 - Sample 3 (0.8kg load)



From these graphs and our initial measurements we can assemble the following results:

Table 1 - Results

	Length (mm)	Width (mm)	Thickness (mm)	Load (kg)	Stress σ (MPa)	$d\varepsilon/dt$	$\ln(\sigma)$	$\ln(d\varepsilon/dt)$
Sample 1	37.0	4.82	1.35	0.6	11.69	9.60E-07	16.27	-13.86
Sample 2	37.81	4.84	1.38	0.7	12.56	1.46E-06	16.35	-13.44
Sample 3	38.94	4.82	1.36	0.8	13.99	3.04E-06	16.45	-12.70

Figure 4 – $\ln(d\varepsilon/dt)$ vs $\ln(\sigma)$ 

With this data we can evaluate the following formula for 'n':

$$\frac{d\varepsilon}{dt} = C_0 \times \sigma^n \times e^{\left(-\frac{Q}{RT}\right)} \quad (4)$$

$$n = 6.433$$

DISCUSSION

The experimental analysis yielded results that clearly follow the standard template of a creep curve. This is most obvious in sample one, which shows all three typical regions;

1. Primary: The sample has undergone a large instantaneous deformation then shows decreasing deformation with time due to strain hardening.
2. Secondary: In secondary, or steady-state creep, the sample deforms at a constant rate with respect to time. This process has been shown to be related to molecular self diffusion as atoms move from grain boundaries that are parallel to the loading to those perpendicular [1]. Also evident is mobile dislocations aligning so as to cancel each other, undoing some of the strain hardening from the primary phase and allowing the material to deform further [1].
3. Tertiary: The sample forms a neck and begins to deform more and more rapidly with time due to decreased area to resist strain.

The second and third samples follow the same pattern, but since they ruptured sooner, and the sample time being the same there are simply fewer data points to illustrate the characteristic curve.

Our experiment was conducted with a change in stress between trials. If we were able to reproduce the experiment with a change in temperature between trials, but fixed stress, we could also evaluate the creep rate formula for activation energy (Q). With ' Q ' and ' n ' we could easily solve for ' C_0 ' and have a complete description of the creep behavior of the material.

CONCLUSION

Our results show that lead, a soft metal, will show substantial creep at room temperature. Specifically, our data shows a relationship between steady state creep and stress at a constant temperature in this material of:

$$\frac{d\varepsilon}{dt} \propto \sigma^{6.433} \quad (5)$$

APPENDIX

DATA

Table 2 – Sample 1 (0.6kg load)

Time	Reading (0.01mm)	Reading (mm)	Delta 'a' (mm)	Delta L	Strain	Slope
0	8.330	0.083	0.000	0.000	0.00E+00	9.60E-07
15	11.400	0.114	0.031	0.015	4.15E-04	
30	11.600	0.116	0.033	0.016	4.42E-04	
45	11.780	0.118	0.035	0.017	4.66E-04	
60	11.940	0.119	0.036	0.018	4.88E-04	
75	12.090	0.121	0.038	0.019	5.08E-04	
90	12.240	0.122	0.039	0.020	5.28E-04	
105	12.350	0.124	0.040	0.020	5.43E-04	
120	12.450	0.125	0.041	0.021	5.57E-04	
135	12.570	0.126	0.042	0.021	5.73E-04	
150	12.690	0.127	0.044	0.022	5.89E-04	
165	12.820	0.128	0.045	0.022	6.07E-04	
180	12.930	0.129	0.046	0.023	6.22E-04	
195	13.040	0.130	0.047	0.024	6.36E-04	
210	13.170	0.132	0.048	0.024	6.54E-04	
225	13.260	0.133	0.049	0.025	6.66E-04	
240	13.380	0.134	0.051	0.025	6.82E-04	
255	13.480	0.135	0.052	0.026	6.96E-04	
270	13.570	0.136	0.052	0.026	7.08E-04	
285	13.670	0.137	0.053	0.027	7.22E-04	
300	13.770	0.138	0.054	0.027	7.35E-04	
315	13.860	0.139	0.055	0.028	7.47E-04	
330	13.970	0.140	0.056	0.028	7.62E-04	
345	14.080	0.141	0.058	0.029	7.77E-04	
360	14.200	0.142	0.059	0.029	7.93E-04	
375	14.300	0.143	0.060	0.030	8.07E-04	
390	14.410	0.144	0.061	0.030	8.22E-04	
405	14.500	0.145	0.062	0.031	8.34E-04	
420	14.620	0.146	0.063	0.031	8.50E-04	
435	14.730	0.147	0.064	0.032	8.65E-04	
450	14.870	0.149	0.065	0.033	8.84E-04	
465	15.010	0.150	0.067	0.033	9.03E-04	
480	15.230	0.152	0.069	0.035	9.32E-04	
495	15.400	0.154	0.071	0.035	9.55E-04	
510	15.610	0.156	0.073	0.036	9.84E-04	
525	15.840	0.158	0.075	0.038	1.01E-03	
540	16.160	0.162	0.078	0.039	1.06E-03	
555	16.480	0.165	0.082	0.041	1.10E-03	
570	16.880	0.169	0.086	0.043	1.16E-03	
585	17.350	0.174	0.090	0.045	1.22E-03	
600	17.950	0.180	0.096	0.048	1.30E-03	
615	18.780	0.188	0.105	0.052	1.41E-03	

Table 3 – Sample 2 (0.7kg load)

Time	Reading (0.01mm)	Reading (mm)	Delta 'a' (mm)	Delta L	Strain	Slope
0	10.550	0.106	0.000	0.000	0.00E+00	1.46E-06
15	12.830	0.128	0.023	0.011	3.02E-04	
30	13.120	0.131	0.026	0.013	3.40E-04	
45	13.410	0.134	0.029	0.014	3.78E-04	
60	13.650	0.137	0.031	0.016	4.10E-04	
75	13.850	0.139	0.033	0.017	4.36E-04	
90	14.070	0.141	0.035	0.018	4.65E-04	
105	14.230	0.142	0.037	0.018	4.87E-04	
120	14.400	0.144	0.039	0.019	5.09E-04	
135	14.560	0.146	0.040	0.020	5.30E-04	
150	14.720	0.147	0.042	0.021	5.51E-04	
165	14.900	0.149	0.044	0.022	5.75E-04	
180	15.090	0.151	0.045	0.023	6.00E-04	
195	15.300	0.153	0.048	0.024	6.28E-04	
210	15.530	0.155	0.050	0.025	6.59E-04	
225	15.760	0.158	0.052	0.026	6.89E-04	
240	16.330	0.163	0.058	0.029	7.64E-04	
255	16.790	0.168	0.062	0.031	8.25E-04	
270	18.160	0.182	0.076	0.038	1.01E-03	
285	20.980	0.210	0.104	0.052	1.38E-03	

Table 4 – Sample 3 (0.8kg load)

Time	Reading (0.01mm)	Reading (mm)	Delta 'a' (mm)	Delta L	Strain	Slope
0	10.270	0.103	0.000	0.000	0.00E+00	3.04E-06
15	14.870	0.149	0.046	0.023	5.91E-04	
30	15.150	0.152	0.049	0.024	6.27E-04	
45	15.580	0.156	0.053	0.027	6.82E-04	
60	16.260	0.163	0.060	0.030	7.69E-04	
75	17.760	0.178	0.075	0.037	9.62E-04	

SAMPLE CALCULATIONS:

Area:

$$A = w \times h = 0.00482 \times 0.00135 = 6.51 \times 10^{-6} m^2$$

Force:

$$F = g(2.96 + 8m) = 9.8(2.96 + 8 \times 0.6) = 76N$$

Stress:

$$\sigma = \frac{F}{A} = \frac{76N}{6.51 \times 10^{-6} m^2} = 11.6MPa$$

Strain:

$$\varepsilon = \frac{\Delta l}{l_0} = \frac{0.01(a_n - a_1)}{2} = \frac{0.01(15.580 - 15.150)}{2 \times 38.94} = 6.82 \times 10^{-4}$$

BIBLIOGRAPHY

1. Callister, W.D. and D.G. Rethwisch, Fundamentals of materials science and engineering : an integrated approach. 3rd ed. 2008, Hoboken, NJ: John Wiley & Sons. xxv, 882 p.