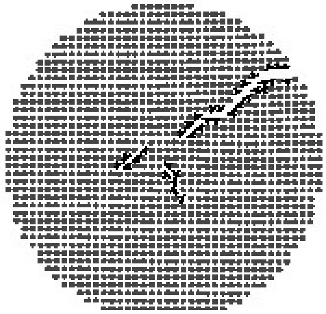


ME 4733: Deformation and Fracture of Engineering Materials

Spring 2002

Problem Set 5 Solution Notes (Friday, 3/8)

1) Hertzberg, 5.3
For the following creep rupture data, construct a Larson-Miller plot (assuming C = 20). Determine the expected life for a sample tested at $650°C$ with a stress of 240MPa, and at $870°C$ with a stress of 35MPa. Compare these values with actual test results of 32,000 and 9000 hr, respectively.

Temp. ($°C$)	Stress (MPa)	Rupture Time (hr)	Temp. ($°C$)	Stress (MPa)	Rupture Time (hr)
650	480	22	815	140	29
650	480	40	815	140	45
650	480	65	815	140	65
650	450	75	815	120	90
650	380	210	815	120	115
650	345	2700	815	105	260
650	310	3500	815	105	360
705	310	275	815	105	1000
705	310	190	815	105	700
705	240	960	815	85	2500
705	205	2050	870	83	37
760	205	180	870	83	55
760	205	450	870	69	140
760	170	730	870	42	3200
760	140	2150	980	21	440
			1095	10	155

Solution:

In Larson-Miller plot, the stress is plotted using logarithm axis.

To determine the life at a given stress and temperature for a given material, enter the curve for the appropriate stress and determine the Larson-Miller parameter. Then calculate the rupture time.

From the curve, at stress of 240MPa the Larson-Miller parameter is 22.5×10^3.

$$(273+650)(20+\log t)=22.5\times10^3$$

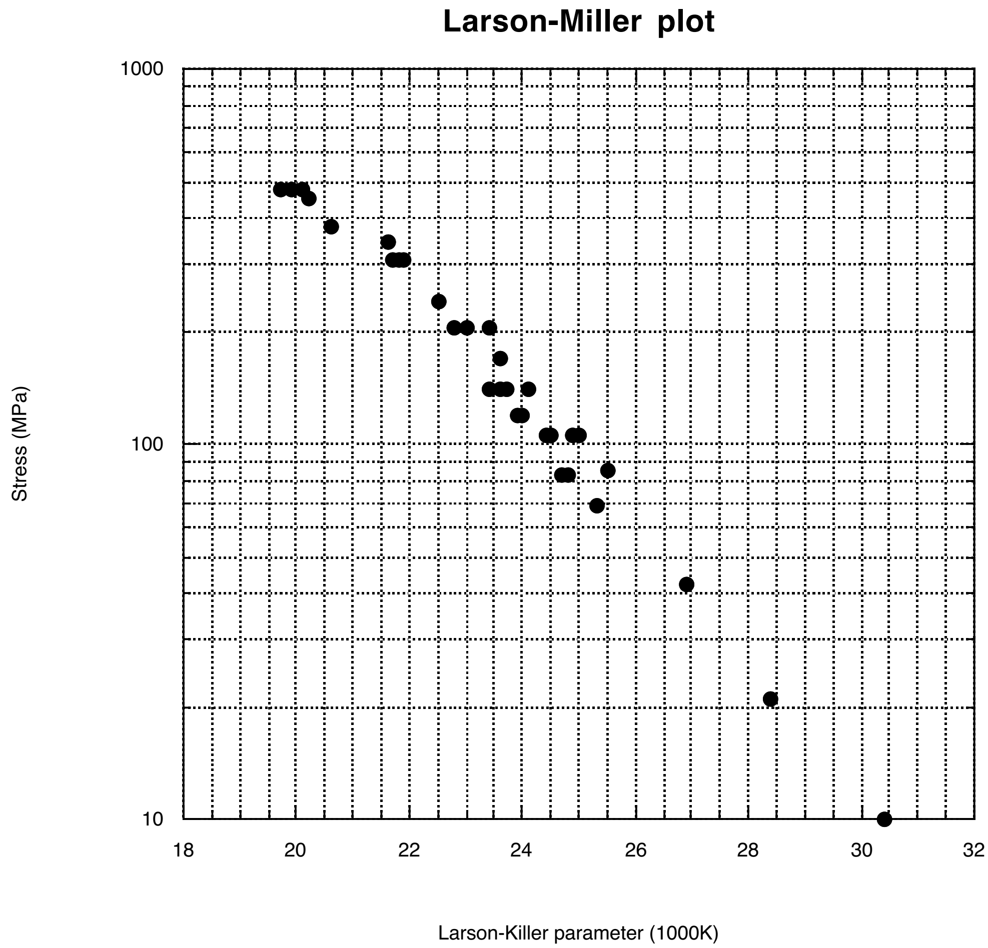
$t=24\times10^3 hr$ (actual test result: 32,000hr)

From the curve, at stress of 35MPa the Larson-Miller parameter is 27.5×10^3.

$$(273+870)(20+\log t)=27.5\times10^3$$

$t=11\times10^3 hr$ (actual test result: 9,000hr)

Temp. ($^\circ K$)	Stress (MPa)	Rupture Time (hr)	Larson-Miller Parameter $T(20+\log t)$ ($10^3 K$)	Temp. ($^\circ K$)	Stress (MPa)	Rupture Time (hr)	Larson-Miller Parameter $T(20+\log t)$ ($10^3 K$)
923	480	22	19.7	1088	140	29	23.4
923	480	40	19.9	1088	140	45	23.6
923	480	65	20.1	1088	140	65	23.7
923	450	75	20.2	1088	120	90	23.9
923	380	210	20.6	1088	120	115	24.0
923	345	2700	21.6	1088	105	260	24.4
923	310	3500	21.7	1088	105	360	24.5
978	310	275	21.9	1088	105	1000	25.0
978	310	190	21.8	1088	105	700	24.9
978	240	960	22.5	1088	85	2500	25.5
978	205	2050	22.8	1143	83	37	24.7
1033	205	180	23.0	1143	83	55	24.8
1033	205	450	23.4	1143	69	140	25.3
1033	170	730	23.6	1143	42	3200	26.9
1033	140	2150	24.1	1253	21	440	28.4
				1368	10	155	30.4


Larson-Miller plot
1000
100
10
Stress (MPa)
18
20
22
24
26
28
30
32
Larson-Killer parameter (1000K)

2) Hertzberg, 5.4

For the data given in the previous problem, what is the maximum operational temperature such that failure should not occur in 5000hr at stress levels of 140 and 200 MPa, respectively.

Solution:

From the curve, at stress level of 140MPa the Larson-Miller parameter is 24.0×10^3.

$$T(20 + \log 5000) = 24.0 \times 10^3$$

$$T = 1013K$$

From the curve, at stress level of 200MPa the Larson-Miller parameter is 23.0×10^3.

$$T(20 + \log 5000) = 23.0 \times 10^3$$

$$T = 971K$$

3) Hertzberg, 5.8

If the Larson-Miller parameter for a given elevated temperature alloy was found to be 26,000, by how much would the rupture life of a sample be estimated to decrease if the absolute temperature of the test were increased from 1100 to 1250K? Assume that the Larson-Miller constant is equal to 20.

Solution:

1100K:

$$26000 = 1100(20 + \log t_1)$$
$$t_1 = 4329 hr$$

1250K:

$$26000 = 1250(20 + \log t_2)$$
$$t_2 = 6.3 hr$$

The rupture life will decrease from 4329*hr* to 6.3 *hr*.

4) Hertzberg, 5.9

Gas turbine component A was originally designed to operate at $700°C$ and exhibited a stress rupture life 800h. Component B in the same section of the turbine was redesigned, thereby allowing its operating temperature to be raised to $725°C$. Could component A be used at that temperature without modification so long as its stress rupture life exceed 100h? (Assume that the Larson-Miller constant for the material is equal to 20.)

Solution:

Using the Larson-Miller relation, we find

$$(273+700)(20+\log 800)=(273+725)(20+\log t)$$

$$\therefore \qquad t = 212hr$$

As such, component A could be used at the higher temperature.