A Load That Cannot Break a Part Breaks It Given Time: the Temperature of Creep Is Measured Against the Melting Point

— at high temperature, a load below the threshold keeps stretching a part over time until it breaks (creep) — the separator is not whether a threshold was crossed but whether time has accumulated, and not the temperature itself but the temperature divided by the melting point — [Paper 659]

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Abstract

The strength of a part is usually stated as a threshold: “it will not break below this stress”. Time does not enter it. But at high temperature, even under a load below the threshold, a part keeps stretching slowly and eventually breaks. This is called creep.How time, temperature and stress act in creep is counted.No new theorem or law is claimed. First, life can be traded for temperature——by the Larson--Miller equation $\mathrm{LMP} = T(20 + \log_{10} t)$, a life of 100 hours at 700 °C becomes 1000 hours at 657.6891 °C, 10000 hours at 618.9042 °C and 100000 hours at 583.2220 °C (Section 2). **Second, one decade of life corresponds to some tens of degrees——the temperature drop needed to extend life by a decade was 42.3109 °C from 100 to 1000 hours, 38.7850 °C from 1000 to 10000 and 35.6822 °C from 10000 to 100000** (Section 2). **Third, and this is the core.The temperature of creep is measured not as temperature itself but divided by the melting point——the rule-of-thumb onset, 0.4 of the melting point, is −32.9 °C for lead, 100.2 °C for aluminium, 451.3 °C for iron and 1204.8 °C for tungsten. Room temperature, 20 °C, is 0.4881 of the melting point for lead and 0.1619 for iron** (Section 3). **Fourth, the separator is not whether a threshold was crossed but whether time has accumulated——with a Norton exponent of 5, lowering the stress by a tenth extends life 1.693509 times and halving it 32 times, but never makes it infinite. Below the strength threshold, time still accumulates** (Sections 4 and 5). **Keywords**: creep, Larson-Miller parameter, melting point, Norton’s law, high-temperature strength.

Scope of this paper (scope note): **No new theorem or law is claimed——the Larson--Miller equation (1952), Norton's power law (1929), the Monkman--Grant relation that life is inversely proportional to the minimum strain rate (1956), and the appearance of creep above roughly 0.3 to 0.5 of the melting point are all known.The premises are simplified ——the Larson--Miller constant is set at 20 (in reality it varies by material), and Norton's exponent at 5. The 0.4 of the melting point is a rule of thumb, not a boundary.The reliability of extrapolation is not discussed——how far long lives can be read from short tests is not the subject.Relation to earlier papers**: **Paper 570 showed that between unlike materials an interference fit vanishes with temperature, and stated that creep, which acts in a hot aluminium hub, lay outside it——this paper takes that seat of creep.Paper 658 showed that tempering can trade time for temperature by an equation of the same form, $T(C + \log t)$——creep can make the same trade in the same form; both are changes carried by diffusion.Paper 457 showed that the rise and the flavour of dough part ways through a difference in temperature coefficients——here too, the rate at which time trades for temperature decides the answer.**What is added is **listing how many degrees one decade of life corresponds to**, showing with a table of temperatures divided by the **melting point that room temperature means different things for different metals**, and **placing the separator on thresholds versus the accumulation of time**.

1. Notation and the Question

Strength: **yield stress and tensile strength are thresholds, "it will not break below this stress", and contain no time.**

Creep: **under a constant load at high temperature, strain grows with time until the part ruptures. The Larson--Miller equation combines the time to rupture t (hours) and temperature T (K) as**

$$\mathrm{LMP} = T\,(20 + \log_{10} t)$$

and takes rupture to occur at the same LMP for the same stress. Norton's power law makes the strain rate proportional to stress to the power n (set at $n = 5$), and life is taken inversely proportional to the strain rate.

Question: **what separates strength, which has no time, from creep, which accumulates it?**

2. Life and Temperature

Computation 2.1: **at $700\ ^\circ\mathrm{C}$ for 100 hours, $\mathrm{LMP} = 21409.30$. The temperatures giving longer lives at the same LMP were derived.**

life	temperature	lowered from 700 °C by
100 hours	700 °C	—
1000 hours	657.6891 °C	42.3109 °C
10000 hours	618.9042 °C	81.0958 °C
100000 hours	583.2220 °C	116.7780 °C

The temperature drops needed to extend life by a decade were 42.3109, 38.7850 and 35.6822 °C.

> **Observation 2.2**
>
> **life can be traded for temperature.Lowering the temperature by a few tens of degrees extends life by a decade, and the longer the life, the smaller the drop needed for each decade——for parts at high temperature, a few tens of degrees decide the order of magnitude of life.**

3. Dividing by the Melting Point

Computation 3.1: **for each metal, room temperature (20 °C) as a fraction of the melting point and the temperature at 0.4 of the melting point were derived.**

metal	melting point	room over melting	0.4 of melting
lead	600.61 K	0.4881	−32.9 °C
tin	505.08 K	0.5804	−71.1 °C
aluminium	933.47 K	0.3140	100.2 °C
copper	1357.77 K	0.2159	270.0 °C
iron	1811.0 K	0.1619	451.3 °C
nickel	1728.0 K	0.1696	418.1 °C
tungsten	3695.0 K	0.0793	1204.8 °C

Observation 3.2

this is the core: the temperature of creep is measured not as temperature itself but divided by the melting point.Whether atoms can move is set by how close the metal is to its melting point. Room temperature is cold for iron, at 0.1619 of its melting point, but for lead it is 0.4881, already past the rule-of-thumb 0.4; for tin it is 0.5804——"high temperature" is not a number on the thermometer but a height relative to the material.

4. The Effect of Stress

Computation 4.1: **with a Norton exponent of $n = 5$ and life inversely proportional to the strain rate, lowering the stress by a tenth extended life 1.693509 times, and halving it 32.000000 times.**

Observation 4.2

lowering the stress only extends life; it does not make it infinite.In the language of a strength threshold, nothing below the threshold breaks. In the language of creep, the strain rate below the threshold is not zero, and life stays finite——the language of strength, which has no time, cannot describe this way of breaking.

5. The Separator

Observation 5.1

the separator is not whether a threshold was crossed but whether time has accumulated, and its temperature is measured against the melting point.Below 0.4 of the melting point, the idea of a strength threshold works well. Above it, the time under load decides how the part breaks——with the same load and the same part, the dimension of time appears or vanishes according to how high the temperature is for the material.

> **Observation 5.2**
>
> **beside Paper 570, Paper 658 and Paper 457.Paper 570 showed that the interference of a steel shaft in an aluminium hub vanishes with temperature, and put creep in hot aluminium outside its scope. 0.4 of aluminium's melting point is 100.2 °C, and above that is the seat. Paper 658 showed that tempering can trade time for temperature by an equation of the same form. Paper 457 showed that the rate of trading time for temperature separates rise from flavour——creep too, as a change carried by diffusion, is on the side where time and temperature can be traded.**

> **Observation 5.3**
>
> **what is not said.The Larson--Miller constant and the Norton exponent are set values, not those of particular materials. The reliability of reading long lives from short tests is not discussed——what is shown is what separates creep from strength, and how its temperature is measured.**

6. Roll Call and Closing

1. **10000 hours at 618.9042 °C** (Computation 2.1): **81.0958 °C lower.**
2. **100000 hours at 583.2220 °C** (Computation 2.1): **life trades for temperature.**
3. **a decade is 42.3109, 38.7850, 35.6822 °C** (Computation 2.1): **tens of degrees decide the order.**
4. **room temperature is 0.4881 of lead's melting point** (Computation 3.1): **past the rule of thumb.**
5. **0.1619 of iron's** (Computation 3.1): **cold.**
6. **0.4 of melting is 451.3 °C for iron** (Computation 3.1): **−32.9 °C for lead.**
7. **measure against the melting point** (Observation 3.2): **the core.**
8. **a tenth less stress gives 1.693509 times the life** (Computation 4.1): **Norton exponent 5.**
9. **half gives 32 times, never infinite** (Observation 4.2): **beyond the language of thresholds.**
10. **whether time has accumulated** (Observation 5.1): **the separator; Papers 570, 658 and 457.**

Closing: **When the strength of a part is stated as "it will not break below this stress", time is not in it.At high temperature, a load below the threshold still breaks a part as time accumulates; a life of 100 hours at 700 °C became 10000 hours at 618.9042 °C, and a decade of life corresponded to about 35 to 42 °C.That "high temperature" is measured against the melting point: room temperature is 0.4881 of lead's and 0.1619 of iron's——whether the dimension of time appears in how a part breaks is set by how high the temperature is for the material.The separator**

is not whether a threshold was crossed but whether time has accumulated, and not the temperature itself but the temperature divided by the melting point.Placed among the earlier papers——in the seat of creep left outside by Paper 570, the same form of trade as in Paper 658 was counted.To be honest——the constant and exponent are set values, and the reliability of extrapolating life is not entered.

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