What Caps a Residual Stress Is Not the Temperature but the Yield

— Cooling fully restrained steel through 600 K gives an elastic stress of **1483.2000** MPa, **4.944000** times the yield — so the residual stress is capped at yield, and every weld above a difference of **121.359223** K settles at the same value — [Paper 562]

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— *From thinking to syncing.* —

Abstract

Welding residual stress is taken to follow how hot the weld became.What this paper shows is that the elastic stress so far exceeds the yield that the cap is set by yielding, and the details of the temperature never enter the answer.No new theorem or law is claimed. First, the elastic view far exceeds the yield——1483.2000 MPa across 600 K, 4.944000 times the yield (Section 2). **Second, even 200 K already exceeds it——494.4000 MPa, 1.648000 times** (Section 2). **Third, and this is the core.Only 121.359223 K is needed to reach the yield——beyond it the residual stress is capped, and how hot the weld became stops entering the answer** (Section 3). **Fourth, so the conclusion is blunt to the assumption——swinging the temperature difference fourfold, from 200 to 800 K, leaves the remaining stress unchanged** (Section 3). **Fifth, tension is always balanced by compression——a 20 mm tensile zone at yield is paid for by 33.3333 MPa across the remaining 180 mm, a ratio of 9.000000** (Section 4). **Sixth, the separator is whether the material can yield——without that escape there is no cap, and it cracks instead** (Section 4). **Keywords**: residual stress, welding, thermal contraction, yielding, self-equilibrium.

Scope of this paper (scope note): **No new theorem or law is claimed——restrained thermal contraction, the cap at yield and self-equilibrium are all standard.No welding practice is recommended——preheat, postheat and heat input are not discussed.The model is a one-dimensional bar——a real weld is three-dimensional and the restraint varies from place to place; only the simplest form, a fully restrained bar, is examined.Temperature dependence of the material constants is excluded——modulus, yield stress and expansion coefficient are held at their room-temperature values, and since yield falls when hot, the real history is more involved than this.Phase transformation is not treated——the martensitic transformation in steel expands and can reverse the sign of the residual stress, and it is not included.Stress-relief annealing is not discussed——how much post-treatment removes is not the subject.It is not said that residual stress always equals the yield——only a fully restrained region reaches it, and looser restraint gives less. What is stated here is a ceiling, not a measurement.Relation to earlier papers**: **Paper 556 showed that what carries most of an external load is not the bolt, and that swinging the assumption 4.394554-fold left the conclusion standing ——the same shape here, with a fourfold swing in temperature leaving the answer unmoved; but the bluntness differs in kind, since there an inequality survived while the values moved, and here the value itself is identical. A cap is the stronger bluntness.Paper 262 showed that there are three ways to break and strength does not decide which, the lowest of the three governing——yielding is one of those three, and here it acts not as a limit but as what supplies the cap. One phenomenon serves as a mode of failure in one question and as a protector in another.Paper 300 showed that sharing a root is decidable——"the ceiling is set by yield" and "tension balances compression" are separate roots.**What is added is **setting the elastic stress against the yield over four temperature differences and measuring the ratio as 4.944000, inverting for the critical difference of 121.359223 K and checking the sign on both sides, placing beside it that even 200 K already exceeds the yield, confirming self-equilibrium over three widths to 12 digits**, and **placing the separator on whether the material can yield**.

1. Notation and the Question

Setting: **a welded region rises above the temperature of its surroundings and then cools.It would contract, and the surrounding metal will not let it.For a fully restrained bar cooling through ΔT, the elastic view gives**

$$\sigma_{\text{elastic}} = \alpha \, \Delta T \, E$$

taking $\alpha = 12 \times 10^{-6}$ per kelvin, $E = 206$ GPa and a yield stress of 300 MPa for steel.

> **Observation 1.1**
>
> **how strongly it is restrained does not appear.Full restraint is assumed, so the degree of restraint enters only as a ceiling——what follows is therefore the worst case.**

> **Observation 1.2**
>
> **the formula is proportional to the temperature difference.So “hotter means more residual stress” is the natural thought——and it is that naturalness which disappears here.**

Question: **how much does the temperature difference affect the stress that remains?**

2. The Elastic View Far Exceeds the Yield

Computation 2.1: **the elastic stress over a range of temperature differences.**

temperature difference	elastic stress	relative to yield
200 K	**494.4000** MPa	**1.648000**
400 K	988.8000 MPa	3.296000
600 K	**1483.2000** MPa	**4.944000**
800 K	1977.6000 MPa	6.592000

> **Observation 2.2**
>
> **every one exceeds the yield.Even the lowest, 200 K, gives 1.648000 times——so this stress never actually occurs: the material yields first.**

> **Observation 2.3**
>
> **at 600 K it lies above four and below five.Measured at 4.944000——that is about the temperature difference of a real weld, so the pull is near five times the yield.**

> **Observation 2.4**
>
> **the boundary was checked.Zero temperature difference gives zero stress——and the relation is monotone. A confirmation that the formula is intact.**

3. So the Ceiling Is Set by Yield, Not by Temperature

Computation 3.1: **inverting for the temperature difference that just reaches the yield.**

$$\Delta T_{\text{critical}} = \frac{\sigma_y}{\alpha E} = \mathbf{121.359223}\ \text{K}$$

Observation 3.2

the inversion is a check.Feeding it back returns exactly 300 MPa——and one per cent below falls short while one per cent above exceeds. Both sides are in view.

Observation 3.3

this is the core.121.359223 K is a small temperature difference for a weld——the real 600 K is 4.944000 times it, so any serious weld passes it.

Observation 3.4

beyond it, how far beyond makes no difference.At 200 K or at 800 K, the remaining tensile stress is capped at the yield——a fourfold swing leaves the answer unchanged. “How hot it became” does not enter this ceiling.

Observation 3.5

the same bluntness as Paper 556.There a 4.394554-fold swing in member geometry left the bolt in the minority——though the bluntness differs in kind: there an inequality survived while the values moved, and here the value itself is identical. A cap is the stronger bluntness.

Observation 3.6

more things need not be measured.Measuring the heat input closely does not move this ceiling——what can be moved is the degree of restraint.

4. The Separator

Computation 4.1: **the balance of tension and compression.With no external load, the resultant over the section must be zero.**

tensile zone	full width	compressive zone	compressive stress
20 mm	200 mm	180 mm	**33.3333** MPa
20 mm	100 mm	80 mm	75.0000 MPa
40 mm	200 mm	160 mm	75.0000 MPa

> **Observation 4.2**
>
> **the resultant is exactly zero.The tensile and compressive areas agree to 12 digits——it follows from the definition, and it is worth confirming that the obvious agrees in numbers.**

> **Observation 4.3**
>
> **the compressive side is diluted.A 20 mm tensile zone at yield needs only 33.3333 MPa across the remaining 180 mm, a ratio of 9.000000——so “the residual stress was measured” differs by an order depending on where. At the weld it is the yield; a little away, a ninth of it.**

> **Observation 4.4**
>
> **the separator is whether the material can yield.Yielding is the escape that stops the stress at a ceiling——in glass or ceramic, which cannot yield, the material cracks the moment $\alpha \Delta T E$ passes the strength. The same restraint and the same temperature difference give a residual stress in one and a crack in the other.**

> **Observation 4.5**
>
> **among the three ways to break of Paper 262, yielding is here the protector.There it was one of the limits, that is, a mode of failure——here the same yielding caps the stress and prevents a crack. One phenomenon serves as failure or as protection according to the question.**

Observation 4.6

separate roots under Paper 300.“The ceiling is set by yield” carries plasticity——“tension balances compression” carries the absence of an external load. The second holds even in a material that cannot yield.

Observation 4.7

what is not said.Residual stress is not claimed always to equal the yield——only a fully restrained region reaches it, and looser restraint gives less. What is stated is a ceiling, not a measurement.

5. Roll Call and Closing

1. **1483.2000 MPa at 600 K** (Computation 2.1): **the elastic view.**
2. **4.944000 times the yield** (Computation 2.1): **measured, then bracketed.**
3. **even 200 K gives 1.648000** (Computation 2.1): **the lowest still exceeds.**
4. **a critical difference of 121.359223 K** (Computation 3.1): **the core.**
5. **feeding it back returns 300 MPa** (Observation 3.2): **both sides change sign.**
6. **a fourfold swing changes nothing** (Observation 3.4): **the cap.**
7. **compression at 33.3333 MPa** (Computation 4.1): **a ratio of 9.000000.**
8. **the resultant is exactly zero** (Observation 4.2): **to 12 digits.**
9. **the separator is the ability to yield** (Observation 4.4): **without it, a crack.**
10. **yielding as protector** (Observation 4.5): **in Paper 262 it was a failure mode.**

Closing: **Welding residual stress is taken to follow how hot the weld became.Yet the elastic view far exceeds the yield——fully restrained steel cooling through 600 K gives $\alpha \Delta T E = 1483.2000$ MPa, 4.944000 times the yield. Even the lowest case, 200 K, gives 1.648000 times, so every one exceeds it: this stress never actually occurs, because the material yields first. Zero temperature difference returns zero stress, as it should.Only 121.359223 K is needed to reach the yield——feeding that back returns exactly 300 MPa, and one per cent below falls short while one per cent above exceeds. The real 600 K of a weld is 4.944000 times it, so any serious weld passes it. Beyond that, how far beyond makes no difference: at 200 K or at 800 K the remaining tensile stress is capped at the yield, and a fourfold swing leaves the answer unchanged. “How hot it became” does not enter this ceiling, and what can be moved is the degree of restraint instead.And the tension is always paid for by compression——with no external load the resultant over the section must vanish, and the tensile and compressive areas agree to 12 digits. A 20 mm tensile zone at yield**

needs only 33.3333 MPa across the remaining 180 mm, a ratio of 9.000000, so “the residual stress was measured” differs by an order depending on where: the yield at the weld, a ninth of it a little away.The separator is whether the material can yield——yielding is the escape that stops the stress at a ceiling, and in glass or ceramic the material cracks the moment $\alpha\Delta TE$ passes the strength. The same restraint and the same temperature difference give a residual stress in one and a crack in the other. Paper 262 showed three ways to break, where yielding was one of the limits, that is a mode of failure; here the same yielding caps the stress and prevents a crack. One phenomenon serves as failure or as protection according to the question. Under Paper 300, “the ceiling is set by yield” carries plasticity while “tension balances compression” carries the absence of an external load.It is also the bluntness of Paper 556——there a 4.394554-fold swing in the assumed member geometry left the bolt in the minority, though the bluntness differs in kind: there an inequality survived while the values moved, and here the value itself is identical. A cap is the stronger bluntness.To be honest——no welding practice is recommended. The model is a one-dimensional bar, while a real weld is three-dimensional with restraint varying from place to place. Modulus, yield and expansion coefficient were held at room-temperature values, and since yield falls when hot the real history is more involved. Phase transformation was excluded, though the martensitic transformation expands and can reverse the sign, and stress-relief annealing was not discussed. Nor is residual stress claimed always to equal the yield: what is stated is a ceiling.

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