The Same “Ten Per Cent” Becomes 1.4641 or 0.7513, Depending on Which Dimension

— a spring rate carries the fourth power of the wire diameter, the inverse cube of the coil diameter and the inverse of the turn count — a wire tolerance of one per cent is amplified into **8.3290** per cent of spring rate — [Paper 558]

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September 2026

— From thinking to syncing. —

Abstract

To stiffen a spring one chooses between a thicker wire, a tighter coil and fewer turns.What this paper shows is that three different exponents live in one formula, so that “change it by the same proportion” is not an instruction at all.No new theorem or law is claimed. First, and this is the core.One “ten per cent” splits into three——1.464100 for the wire, 0.751315 for the coil, 0.909091 for the turns (Section 2). **Second, the exponents can be recovered without the formula——log-log slopes return 4.000000, −3.000000 and −1.000000** (Section 2). **Third, one direction differs from the other two——only the wire diameter exceeds one; the other two fall below it** (Section 2). **Fourth, tolerance is amplified——one per cent on the wire becomes 8.3290 per cent of spring rate** (Section 3). **Fifth, only the wire improves two things at once——ten per cent thicker gives 1.464100 times the stiffness and 0.751315 times the stress at equal load** (Section 3). **Sixth, the separator is that the exponents differ by dimension——were they equal, “ten per cent” would have one meaning; they are not, so it has none** (Section 4). **Keywords**: coil spring, spring rate, torsional stress, dimensional sensitivity, spring design.

Scope of this paper (scope note): No new theorem or law is claimed——the spring-rate formula and the torsional stress formula are standard.No spring design is recommended——which dimension to adjust is not stated; only what happens when one is.Manufacturing constraints are excluded——neither the cost of a thicker wire nor the smallest coil that can be wound is included, so “adjust the wire” is not advised.End coils and terminations are not treated——the active turn count is taken as given.Large deflections are excluded——only the linear range, short of coils closing on one another.Fatigue and set are not treated——cyclic loading is not the subject.No stress-concentration factor is applied——the Wahl correction is omitted, so the stresses of Section 3 are to be read only as ratios.Relation to earlier papers: Paper 372 showed that halving an area does not halve the species, obtaining **0.840896** under an exponent of 0.25——the wire ratio that halves the spring rate here is the same **0.840896**: the exponents $1/4$ and 4 are reciprocals, so one number appears with the direction of entry reversed, and this is no coincidence. That paper concerns one exponent, this one three living together.Paper 335 showed that a round trip changes the exponent, and carries the same **0.840896**——that paper moves an exponent, while this one holds three still and sets them side by side.Paper 300 showed that sharing a root is decidable——“the exponents differ by dimension” and “tolerance is amplified” share one root, the exponent of four.What is added is recovering the three exponents as log-log slopes without reading the formula, showing to 12 digits that one “ten per cent” splits into **1.464100**, **0.751315** and **0.909091**, measuring the tolerance amplification as **8.3290** per cent, showing that the wire alone improves stiffness and stress together, and placing the separator on the exponents being unequal.

1. Notation and the Question

Setting: for a helical spring of wire diameter d, mean coil diameter D, active turns n and shear modulus G,

$$k = \frac{G\,d^4}{8\,D^3\,n}$$

and the torsional stress at a given load F is $\tau = 8FD/(\pi d^3)$.

Observation 1.1

three dimensions enter with three different exponents.Plus four, minus three, minus one——all three wear the face of “a dimension”, and their effects differ by orders.

Observation 1.2

the question on the floor has the shape of a proportion.“Make it about ten per cent stiffer”——if the answer depends on which dimension moves by ten per cent, that phrase is not an instruction.

Question: **how differently does one “ten per cent” land?**

2. One Ten Per Cent Splits Into Three

Computation 2.1: **from a steel spring of wire 2 mm, coil 16 mm and 10 turns (rate 3872.070313 N/m), raising each dimension by a tenth in turn.**

dimension raised a tenth	ratio of spring rate	exponent
wire diameter	**1.464100**	1.1^{4}
coil diameter	**0.751315**	1.1^{-3}
turns	**0.909091**	1.1^{-1}

> **Observation 2.2**
>
> **this is the core.One “ten per cent” scatters from 1.464100 to 0.751315——a spread of 1.95-fold between the largest and smallest, and in opposite directions besides.**

> **Observation 2.3**
>
> **one direction differs.Only the wire exceeds one; coil and turns fall below——the same act of “making it larger” stiffens in one place and softens in two.**

Computation 2.4: **recovering the exponents without reading the formula, as numerical log-log slopes.**

dimension	log-log slope
wire diameter	**4.000000**
coil diameter	**−3.000000**
turns	**−1.000000**

Observation 2.5

this is a check.The exponents written in the formula and the slopes taken numerically from the function agree to within 10^{-6}——an implementation departing from the formula would fail it, and the ratio 1.464100 was separately matched to 1.1^{4} to 12 digits.

Observation 2.6

“change it ten per cent” is not an instruction.Without naming the dimension, the ratio is undetermined——speaking in proportions frees one from the units of a dimension, and not from its exponent.

3. Amplified Tolerance, and the Wire’s Double Gain

Computation 3.1: placing a tolerance on the wire and reading the band in spring rate.

wire tolerance	ratio of spring rate	band
±1 per cent	0.960596–1.040604	1.083290
±2 per cent	0.922368–1.082432	1.173536
±5 per cent	0.814506–1.215506	1.492323

Observation 3.2

one per cent becomes 8.3290 per cent.Above 1.08 and below 1.09 (measured 1.083290)——a per cent at the wire drawer returns eightfold at the spring rate. That is the price of the fourth power.

Observation 3.3

leverage and volatility are one fact seen twice.The most effective knob is the most demanding of tolerance——the choice is between “effective but needing control” and “inert but stable”, and not both.

Observation 3.4

the wire ratio that halves the rate is $\mathbf{0.840896}$.Feeding it back returns exactly 0.5, to 12 digits——this number is already in the corpus: Paper 372 obtained “halving the area leaves $\mathbf{0.840896}$ of the species” under an exponent of 0.25, and Paper 335 carries it too. The exponents $1/4$ and 4 are reciprocals, so one number appears with the direction of entry reversed, which is no coincidence.

Computation 3.5: the stress at equal load with a tenth more wire diameter: $\mathbf{0.751315}$, matching 1.1^{-3} to 12 digits.

Observation 3.6

only the wire improves two things at once.Stiffness rises to $\mathbf{1.464100}$ and stress falls to $\mathbf{0.751315}$——a design knob usually improves one thing and worsens another, as the preload of Paper 556 and the pressure angle of Paper 557 both did. This is the uncommon case where both move the same way.

Observation 3.7

the same $\mathbf{0.751315}$ appears twice.As the rate ratio for a tenth more coil diameter, and as the stress ratio for a tenth more wire——both are 1.1^{-3}: one exponent acting on two different partners, so one number carries two meanings.

4. The Separator

Observation 4.1

the separator is that the exponents differ by dimension.Were all three equal, “change it ten per cent” would have one meaning——they are not, so it has none. The separator is not that the formula is a product of powers, but whether the exponents agree.

Observation 4.2

a product of powers adds when spoken in proportions.Taking logarithms, $\ln k = 4\ln d - 3\ln D - \ln n$ plus a constant——so small changes add their effects. The coefficients being 4, -3 and -1, what adds is not the proportions but the proportions weighted by exponents.

Observation 4.3

one root, under Paper 300.“The exponents differ by dimension” and “tolerance is amplified” both come from the exponent of four——flatten every exponent to one and both vanish. The usual verdict in this body of work is separate roots, and here it is one.

Observation 4.4

what is not said.“Adjust the wire” is not advised——the cost of thicker wire and the smallest windable coil were left out. Being effective and being the right choice are not the same.

5. Roll Call and Closing

1. **wire, a tenth: 1.464100** (Computation 2.1): **matching 1.1^4 to 12 digits.**
2. **coil, a tenth: 0.751315** (Computation 2.1): **1.1^{-3}.**
3. **turns, a tenth: 0.909091** (Computation 2.1): **1.1^{-1}.**
4. **slopes 4.000000, -3.000000, -1.000000** (Computation 2.4): **recovered without the formula.**
5. **± 1 per cent gives a band of 1.083290** (Computation 3.1): **8.3290 per cent.**
6. **halving takes a wire ratio of 0.840896** (Observation 3.4): **already held by Paper 372 and Paper 335.**
7. **stress falls to 0.751315** (Computation 3.5): **stiffer and less stressed.**
8. **the same 0.751315 twice** (Observation 3.7): **one exponent, two partners.**
9. **the separator is unequal exponents** (Observation 4.1): **equalise them and the phrase means something.**
10. **the two facts share a root** (Observation 4.3): **both from the fourth power.**

Closing: **To stiffen a spring one chooses between a thicker wire, a tighter coil and fewer turns.Yet three different exponents live in one formula, so that “change it by the same proportion” is not an instruction at all——from a spring of wire 2 mm, coil 16 mm and 10 turns, raising each dimension by a tenth gives 1.464100, 0.751315 and**

0.909091. The spread is 1.95-fold and the directions differ, only the wire exceeding one. The exponents can be recovered without reading the formula, log-log slopes returning 4.000000, −3.000000 and −1.000000 to within 10^{-6}, which an implementation departing from the formula would fail. Speaking in proportions frees one from the units of a dimension and not from its exponent.And the fourth power returns tolerance amplified——a wire tolerance of one per cent becomes a band of 1.083290, that is 8.3290 per cent of spring rate. Leverage and volatility are one fact seen twice: the most effective knob is the most demanding of tolerance, and the choice is between "effective but needing control" and "inert but stable". The wire ratio that halves the rate, 0.840896, is already in the corpus, Paper 372 having obtained it under an exponent of 0.25 and Paper 335 carrying it too; since 1/4 and 4 are reciprocal exponents, the same number appears with the direction of entry reversed, and this is no coincidence.The wire alone improves two things at once——a tenth thicker gives 1.464100 times the stiffness and 0.751315 times the stress at equal load. A design knob usually improves one thing and worsens another, as the preload of Paper 556 and the pressure angle of Paper 557 both did, and this is the uncommon case where both move together. That 0.751315 is also the rate ratio for a tenth more coil diameter: one exponent, 1.1^{-3}, acting on two different partners.The separator is that the exponents differ by dimension——were all three equal, "change it ten per cent" would have one meaning, and they are not, so it has none. What separates is not that the formula is a product of powers but whether the exponents agree. Under Paper 300 the two facts here share one root, the exponent of four: flatten every exponent to one and both vanish.To be honest——no spring design is recommended. The cost of thicker wire and the smallest windable coil were left out, so "adjust the wire" is not advised: being effective and being the right choice are not the same. End coils were not treated and the active turn count taken as given; only the linear range was examined, short of coils closing; fatigue and set were left aside; and with the Wahl correction omitted, the stresses here are to be read only as ratios.

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