“Better Lubrication Means Less Friction” Holds Only on the Near Side of the Minimum

— Adding a boundary term, which fades as the film thickens, to a fluid term, which grows with it, gives a friction coefficient with a minimum of 0.008686 at a film thickness of $x = 5.730000$ — the separator is whether the film is thicker than the roughness of the surfaces — [Paper 711]

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— *From thinking to syncing.* —

Abstract

Better lubrication is supposed to mean less friction. But the friction coefficient has a minimum, and beyond it better lubrication means more.Where that minimum lies, and why it exists at all, is counted here by separating two terms.No new theorem or law is claimed. First, and this is the core. The friction coefficient has a minimum——0.008686 at a film thickness of $x = 5.730000$, which is 0.086857 of the boundary value 0.100000 (Section 2). **Second, beyond it, friction rises——at $x = 30$ it is 0.030111, which is 3.466730 times the minimum** (Section 2). **Third, neither term is non-monotone——the boundary term falls from 0.050000 at $x = 1$ to 0.000990 at $x = 10$, and the fluid term rises from 0.001000 to 0.010000** (Section 3). **Fourth, the non-monotonicity lives only in the sum ——an interior valley appears only when a falling term and a rising term are added** (Section 3). **Fifth, so one word, “lubrication”, hides two mechanisms——two things called by one name act in opposite directions along the same axis** (Section 4). **Sixth, the separator is whether the film is thicker than the roughness——below it the boundary term governs, above it the fluid term does** (Section 4). **Keywords**: Stribeck curve, boundary lubrication, fluid-film lubrication, minimum of friction, non-monotonicity, sum of two terms.

Scope of this paper (scope note): **No new theorem or law is claimed——the Stribeck curve, the distinction between boundary and fluid-film lubrication, and the minimum of the friction coefficient are all standard (Stribeck 1902, Hamrock et al. 2004).No real bearing is claimed——a boundary friction of 0.10 and a fluid coefficient of 0.001 are representative values and move greatly with material, oil and load.No Stribeck number is constructed——speed, viscosity and load are not combined; only a dimensionless measure x of film thickness is used, and the position of the valley depends on how x is scaled.Wear and heat are not treated——the progress of wear, the temperature rise from friction and the action of additives are not treated.Nothing is fitted——no fit to a measured Stribeck curve is made; only the form of a sum of two terms is examined.Relation to earlier papers**: **Paper 710 showed that when return is proportional to size and cost grows as the 1.5 power, an optimal size appears strictly inside——there the sum of two terms produced a hill. Here the same form produces a valley. A competition need not produce a maximum.**What is added is **putting the position and depth of the valley at 5.730000 and 0.008686**, **putting the ratio to the boundary value at 0.086857**, **showing the return to 3.466730 times the minimum beyond it**, **confirming each term separately to be monotone so that the non-monotonicity comes from the sum**, and **placing the separator on the film exceeding the roughness**.

1. Notation and the Question

Setting: **write the friction coefficient as a sum of two terms. One comes from the surfaces touching directly and fades as the film thickens; the other is the resistance of shearing the oil and grows with the film.**

$$\mu(x) = \frac{\mu_b}{1 + (x/x_0)^2} + c\,x, \qquad \mu_b = 0.10, \quad x_0 = 1, \quad c = 0.001$$

Here x is a dimensionless measure of film thickness.

Question: **does better lubrication always mean less friction?**

2. There Is a Valley

Computation 2.1: **the friction coefficient was derived at each film thickness.**

film thickness	friction coefficient
0.0000	0.100000
0.5000	0.080500
1.0000	0.051000
3.0000	0.013000
5.7300	0.008686
10.0000	0.010990
20.0000	0.020249
30.0000	0.030111

> **Observation 2.2**
>
> this is the core: the minimum lies not at an end but in the middle.0.008686 at $x = 5.730000$, which is 0.086857 of the boundary value 0.100000, and beyond it the curve turns——at $x = 30$ it has returned to 0.030111, 3.466730 times the minimum.

> **Observation 2.3**
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> so “better is better” holds only on the near side.To the right of the valley, the effort of thickening the film adds friction directly——one and the same action acts in opposite directions according to where one stands.

3. The Non-Monotonicity Lives Only in the Sum

Computation 3.1: taken separately, each term is monotone.

film thickness	boundary term alone	fluid term alone
1	0.050000	0.001000
10	0.000990	0.010000

Observation 3.2

looking at either term alone, no valley is visible.The boundary term falls monotonically and the fluid term rises monotonically——neither mechanism contains an optimal film thickness.

Observation 3.3

the valley appears only on adding them.Add a falling term to a rising one and somewhere they must change places——the optimum is a property not of the parts but of their combination.

Observation 3.4

the depth is set by the ratio of the two strengths.A smaller fluid coefficient deepens the valley and moves it to the right——the position of the valley is a property of the oil, so changing the oil moves the design point.

Observation 3.5

one word, “lubrication”, hides both.Boundary and fluid-film lubrication go by one name and act in opposite directions along the same axis——received as one word, the behaviour is assumed monotone.

4. The Separator

Observation 4.1

the separator is whether the film is thicker than the roughness of the surfaces.Below it the surfaces touch and the boundary term governs; above it the resistance of shearing the oil does——the valley is where that handover happens.

Observation 4.2

beside Paper 710.Paper 710 showed an optimal size appearing strictly inside when return is proportional to size and cost grows as the 1.5 power——there the sum produced a hill; here it produces a valley. A competition need not produce a maximum, and which it produces follows from the directions of the two terms.

Observation 4.3

what is not said.Nothing is fitted to a real bearing or oil, and neither wear nor heat is treated——what is shown is that the non-monotonicity lives only in the sum.

5. Roll Call and Closing

1. **the valley at $x = 5.730000$** (Computation 2.1): **in the middle, not at an end.**
2. **friction 0.008686 there** (Computation 2.1): **the core.**
3. **0.086857 of the boundary** (Observation 2.2): **an order lower.**
4. **0.030111 at $x = 30$** (Computation 2.1): **it comes back.**
5. **3.466730 times the minimum** (Observation 2.2): **overshooting costs.**
6. **boundary alone $0.050000 \to 0.000990$** (Computation 3.1): **monotone fall.**
7. **fluid alone $0.001000 \to 0.010000$** (Computation 3.1): **monotone rise.**
8. **neither contains an optimum** (Observation 3.2): **not a property of the parts.**
9. **the valley is in the sum** (Observation 3.3): **a property of the combination.**
10. **film against roughness** (Observation 4.1): **the separator; Paper 710.**

Closing: **“Better lubrication means less friction” holds only on the near side of the minimum.Adding a boundary term to a fluid term gives a friction coefficient with a minimum of 0.008686 at $x = 5.730000$, which is 0.086857 of the boundary value 0.100000——beyond it the curve turns, reaching 0.030111 at $x = 30$, 3.466730 times the minimum.Yet neither term is non-monotone——the boundary term falls from 0.050000 to 0.000990 and the fluid term rises from 0.001000 to 0.010000.The valley appears only on adding a falling term to a rising one——the optimum is a property not of the parts but of their combination.And one word, “lubrication”, hides two mechanisms acting in opposite directions along one axis.The separator is whether the film is thicker than the roughness of the**

surfaces.Placed among the earlier papers——in Paper 710 the sum of two terms produced a hill; here the same form produces a valley.To be honest——nothing is fitted to a real bearing or oil, and every coefficient is representative.

References

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