A Riveted Plate Is Only Half a Plate

— The pitch at which the plate's tensile capacity meets the rivet's shear capacity is **1.981748** rivet diameters, and the joint efficiency there is **0.495395** — two rivets to a pitch raise it to **0.662561**, and it never reaches one — [Paper 563]

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— *From thinking to syncing.* —

Abstract

To strengthen a joint, the natural move is to add rivets.What this paper shows is that a rivet requires a hole, that the hole removes plate, and that the joint efficiency therefore has a ceiling below one.No new theorem or law is claimed. First, the two capacities move oppositely——a wider pitch raises the plate's capacity while the rivet's stays at 78.5398 kN (Section 2). **Second, and this is the core.Efficiency is greatest where the two meet——at a pitch of 1.981748 diameters, with an efficiency of 0.495395** (Section 2). **Third, it falls either way——0.200000 at 25 mm and 0.245437 at 80 mm** (Section 3). **Fourth, closing it fully gives zero——at a pitch of one diameter no plate remains** (Section 3). **Fifth, two rows raise it without reaching one——to 0.662561** (Section 3). **Sixth, the separator is whether the fastener cuts away what it fastens——a fastening that removes nothing has no such ceiling** (Section 4).
Keywords: riveted joint, joint efficiency, net section, loss from holes, structural design.

Scope of this paper (scope note): **No new theorem or law is claimed——riveted-joint efficiency and net section are standard.No joint is designed——safety factors, edge distances and plate buckling are excluded.Bearing failure is excluded——a plate can also be crushed by the rivet; only plate tension and rivet shear are counted here, and adding the third mode lowers the ceiling further.Staggered patterns are not treated——"two rows" is counted as two rivets to a pitch, without the diagonal failure paths.Friction is excluded——a slip-critical bolted joint transmits by friction and is an entirely different accounting.Stress concentration at the hole is excluded——only the net section is counted, and the edge of the hole belongs to Paper 343.Rivets are not called inferior——having a ceiling and being the wrong choice are different things.Relation to earlier papers**: **Paper 550 showed that a line's capacity is its minimum stage and that widening helps either fully or not at all——this joint is also a minimum, but there only the constraining stage was widened, giving a step from one to zero, while here moving the pitch moves both capacities at once and a peak appears. Under one minimum rule, the shape depends on what the knob touches.Paper 557 showed that the angle strengthening a tooth points against the angle smoothing the drive——the pitch here has the same shape, one knob moving two goods oppositely, but that conflict had no crossing and forced a choice, while this one is optimised exactly at the crossing. Whether the conflict has a summit is what differs.Paper 300 showed that sharing a root is decidable ——"efficiency has a ceiling" and "the optimum lies at the crossing" are separate roots.**What is added is **locating the balancing pitch at $\mathbf{1.981748}$ diameters and confirming the equality by inversion**, **measuring the maximum efficiency as $\mathbf{0.495395}$ and checking that it falls on both sides**, **confirming to 12 digits that closing the pitch to one diameter gives zero**, **setting the two-row value of $\mathbf{0.662561}$ beside it**, and **placing the separator on whether the fastener cuts away what it fastens**.

1. Notation and the Question

Setting: **plates of thickness t are fastened by rivets of diameter d at a pitch p, and one pitch carries the lesser of two capacities.**

$$F = \min\left(\sigma_t\, t\,(p-d),\ \tau\,\pi d^2/4\right)$$

the first being the plate tearing between holes and the second the rivet shearing.Joint efficiency is $\eta = F/(\sigma_t t p)$, the ratio to an unpierced plate.

Observation 1.1

the numerator carries $p-d$ and the denominator p.A diameter of plate is lost before anything is loaded—— η can reach one only if $d = 0$.

> **Observation 1.2**
>
> **a minimum appears.The same form as the serial line of Paper 550——only the lesser acts, and the greater idles.**

Question: **where should the pitch be placed for the greatest efficiency?**

2. Where the Two Capacities Cross

Computation 2.1: **plates 10 mm thick of 400 MPa tensile strength, rivets 20 mm in diameter of 250 MPa shear strength.**

quantity	value
shear capacity of one rivet	**78.5398** kN
plate capacity at pitch p	4000.0000 kN/m $\times (p - d)$

> **Observation 2.2**
>
> **one moves and the other does not.A wider pitch raises the plate capacity linearly while the rivet stays at 78.5398 kN——so which of them is the lesser changes along the way.**

Computation 2.3: **the pitch at which they are equal.**

quantity	value
balancing pitch	**0.039635** m (**1.981748** diameters)
efficiency there	**0.495395**

> **Observation 2.4**
>
> **this is the core.At best 0.495395, short of half an unpierced plate——above 0.49 and below 0.50, measured before being bracketed.**

Observation 2.5

the inversion is a check.At that pitch the two capacities agree——confirming separately that it solves the equation.

Observation 2.6

efficiency is always below one.So long as there is a hole, $p - d < p$——however well the pitch is chosen, part of the plate is discarded at the outset.

3. It Falls Either Way

Computation 3.1: **moving the pitch and reading capacity and efficiency.**

pitch	plate	rivet	efficiency
25 mm	20.0000 kN	78.5398 kN	**0.200000**
30 mm	40.0000 kN	78.5398 kN	0.333333
39.6 mm	78.5398 kN	78.5398 kN	**0.495395**
50 mm	120.0000 kN	78.5398 kN	0.392699
80 mm	240.0000 kN	78.5398 kN	**0.245437**

Observation 3.2

it falls on both sides of the peak.At 0.9 and at 1.1 times the optimum——a single point is not called a maximum.

Observation 3.3

the two sides fail differently.Closer, the plate runs short; wider, the rivets do——on the left the holes are too near, on the right too few. The same fall in efficiency, and a different thing missing.

> **Observation 3.4**
>
> closing it fully gives zero.At a pitch of one diameter the efficiency is exactly zero, to 12 digits——the holes touch and no plate remains. A boundary.

Computation 3.5: two rivets to a pitch gives a pitch of **0.059270** m and an efficiency of **0.662561**.

> **Observation 3.6**
>
> higher, and still short of one.Above 0.65 and below 0.68——more rows carry more per hole, so a wider pitch can be afforded; and so long as there is a hole, the ceiling stays short of one.

4. The Separator

> **Observation 4.1**
>
> the separator is whether the fastener cuts away what it fastens.A rivet or a bolt needs a hole to enter——welding and bonding remove nothing and so carry no such ceiling, carrying another instead, as the lap joint of Paper 561 does. “Efficiency below one” is not a weakness of rivets but a property of any fastening that needs a hole.

> **Observation 4.2**
>
> the knob differs from Paper 550.There only the constraining stage was widened, so the help stepped from one to zero——here moving the pitch moves both capacities at once, the plate rising and the denominator with it, so a peak appears instead of a step. Under one minimum rule, the shape depends on whether the knob touches one side or both.

> **Observation 4.3**
>
> and the shape differs from Paper 557.There the pressure angle moved tooth strength and contact ratio oppositely, with no crossing, so a choice was forced——here the crossing itself is the optimum. Whether the conflict has a summit is what differs.

Observation 4.4

separate roots under Paper 300.“Efficiency has a ceiling” carries the hole removing plate——“the optimum lies at the crossing” carries the two capacities moving oppositely. Shrink the hole to nothing and the first vanishes while the second survives.

Observation 4.5

what is not said.Rivets are not called inferior——having a ceiling and being the wrong choice are different things, and with bearing failure and friction excluded, real design is more involved than this.

5. Roll Call and Closing

1. **one rivet, 78.5398 kN** (Computation 2.1): **independent of pitch.**
2. **balancing pitch 1.981748 diameters** (Computation 2.3): **the crossing.**
3. **maximum efficiency 0.495395** (Computation 2.3): **the core; short of half.**
4. **the two agree there** (Observation 2.5): **the inversion checks.**
5. **0.200000 at 25 mm** (Computation 3.1): **the closer side.**
6. **0.245437 at 80 mm** (Computation 3.1): **the wider side.**
7. **zero at one diameter** (Observation 3.4): **a boundary, to 12 digits.**
8. **two rows give 0.662561** (Computation 3.5): **higher, still short of one.**
9. **the separator is a fastener that cuts** (Observation 4.1): **no such ceiling otherwise.**
10. **Paper 550 steps, this peaks** (Observation 4.2): **the knob acts differently.**

Closing: **To strengthen a joint, the natural move is to add rivets.Yet a rivet requires a hole, and the hole removes plate——one pitch carries the lesser of the plate tearing between holes and the rivet shearing, the first rising with the pitch and the second fixed at 78.5398 kN. So efficiency is greatest where the two meet, at a pitch of 1.981748 diameters, giving 0.495395. That lies above 0.49 and below 0.50, measured before being bracketed, and the equality at that pitch was confirmed by inversion. At best it falls short of half an unpierced plate: with a hole, $p - d < p$, so however well the pitch is chosen part of the plate is discarded at the outset.And it falls either way from there——0.200000 at 25 mm and 0.245437 at 80 mm, lower at 0.9 and at 1.1 times the optimum. The two sides fail differently: closer, the plate runs short; wider, the rivets do. The same fall, a different thing missing. Closing the pitch to one diameter gives exactly zero, the holes touching with no plate between. Two rivets to a pitch raise it to**

0.662561, and even that stops short of one.The separator is whether the fastener cuts away what it fastens——a rivet or a bolt needs a hole to enter, while welding and bonding remove nothing and carry another ceiling instead, as the lap joint of Paper 561 does. “Efficiency below one” is not a weakness of rivets but a property of any fastening that needs a hole. Under Paper 300, “efficiency has a ceiling” carries the hole removing plate while “the optimum lies at the crossing” carries the two capacities moving oppositely.Placed among the earlier papers——Paper 550 was also a minimum rule, but there only the constraining stage was widened and the help stepped from one to zero, while here the pitch moves both capacities at once and a peak appears. Under one minimum rule, the shape depends on whether the knob touches one side or both. Paper 557 was also one knob moving two goods oppositely, but that conflict had no crossing and forced a choice, whereas here the crossing itself is the optimum.To be honest——no joint is designed. Safety factors, edge distances and plate buckling were excluded, and bearing failure — the plate crushed by the rivet — was left out, so counting the third mode lowers the ceiling further. “Two rows” was counted as two rivets to a pitch, without the diagonal failure paths of a staggered pattern; slip-critical bolted joints transmitting by friction are an entirely different accounting; and the edge of the hole belongs to Paper 343. Nor are rivets called inferior: having a ceiling and being the wrong choice are different things.

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