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Poster Project Report - Avoiding Jams During Assembly

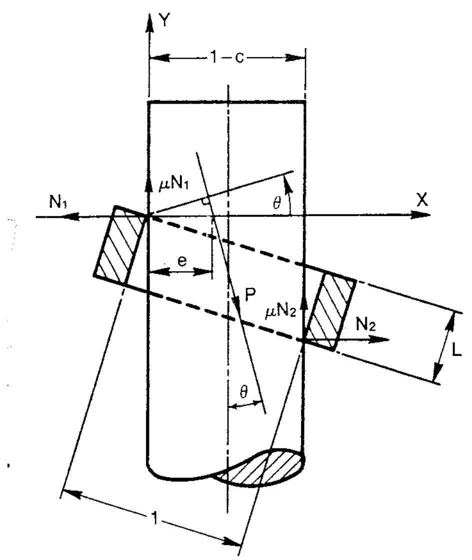
Problem
When a part with a hole needs to be assembled onto a peg, a problem arises. If precautions are not taken, the part could jam on the peg, seizing the assembly. This could bring devastating consequences, such as: ruining a machine, and/or ruining a part or peg, both of which cost significant time and money.

Applications
In the manufacturing process, usually a robotic arm assembles such parts onto pegs. Other applications when robotic arms are not used include:

1) *Battery lid assembly*- jamming could occur on one or both of the terminals when the battery's lid is added.
2) *Bolt-action rifle*- if the bolt is not oiled and becomes tilted, jamming is a possibility.
3) *Car wheel*- everyone has changed the wheel and tire on a car when winter comes around and studs need to go on. When the five holes need to fit over their respective lug nuts, jamming may occur on one or more of the pegs, making the task very frustrating.
4) *Bolt and washer assembly*- or any part that slides over a peg. This is the case considered in this report. Jamming occurs due to two frictional forces opposing the assembly force (force used to slide the washer down the bolt.

G. Bothroyd, Professor of Mechanical Engineering at the University of Massachusetts, provides a solution to jamming problems like case four. He proves that a part will not jam on its peg if his derived equation, relating the parts' dimensions and coefficient of friction, is satisfied. We call this the Anti-Jam Equation.

Derivation of Anti-Jam Equation
Bothroyd begins his derivation by considering an assembly force, P, acting through the centroid of the washer which slides over a bolt. The washer tilts until two of its inside corners touch the bolt, and the analysis begins.



Part Assembled on a Peg

Figure 1. Shows the scenario where a jam happens. N1 and N2 are reaction forces of the part on the peg. P is the assembly force that moves the part downward. L is the thickness of the part and c is the tolerance or gap between the peg and inside diameter of the part. An x-y coordinate system is established with its origin at the left contact point of the part and peg. Copied from article, "Avoiding Jams During Assembly," provided by Dr. Odom.

Writing the summation equation for the y direction with the downward force greater than the upward force yields:

$$P\cos\theta > \mu(N_1 + N_2)$$

If this equation is satisfied, the part will slide freely down the peg. Equilibrium in the x-direction yields:

$$P\sin\theta + N_2 - N_1 = 0$$

And summing the moments around the origin,

$$\{[1 + L^2 - (1 - c)^2]^{1/2} + \mu(1 - c)\}N_2 - eP\cos\theta = 0$$

Combining the preceding equations gives,

$$\left(\frac{2\mu e}{q} - 1\right)\cos\theta + \mu\sin\theta < 0$$

Where

$$q = [1 + L^2 - (1 - c)^2]^{1/2} + \mu(1 - c).$$

If theta=0, P acts along the axis of the peg and,

$$2\mu e < q$$

Or

$$e = \frac{m}{2}(1 - c)$$

Combining the last two equations gives,

$$1 + L^2 > (1 - c)^2 [\mu^2(m - 1)^2 + 1]$$

For the part to free itself from a wedged position m=2 and,

$$1 + L^2 > (1 - c)^2 (\mu^2 + 1) \qquad \text{Eq 1}$$

Designing for No Jamming

If Eq 1 is satisfied, the assembly will not jam. It can be used to design for a situation given two parameters and solving for the third. For example, with a coefficient of friction of 0.5 and a washer thickness, L, of .05 inches,

1+.05^2 > (1-c)^2 * (.5^2 + 1)

Solving this means that c must be greater than .104 inches, which is the minimum gap that can be between the bolt and washer. See Figure 2 for a graphical representation of this relationship.

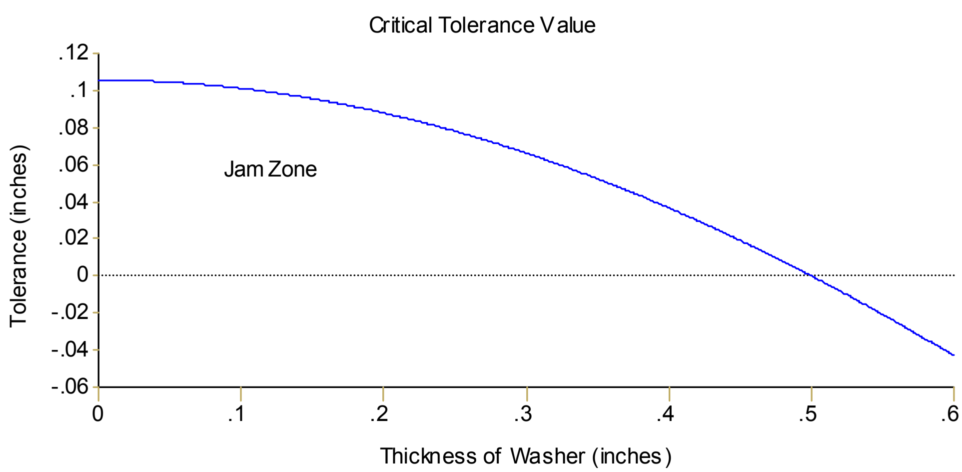


Figure 2. Shows the relationship between L and c in Eq 1 with a coefficient of friction of 0.5. The curve represents the smallest gap the assembly can handle without the possibility of jamming for washer thicknesses 0-.6 inches. All combinations under the curve could jam, and all combinations above the curve will not. Notice as the washer thickness increases, the minimum washer-bolt gap decreases. When a washer thickness of half an inch is achieved, any gap will work.