# Addressing the Common Root Cause of Bolted Joint Loosening in PV Rack/Tracker Structures

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Poster QR Code

## Problem Statement

**Background/Problem Statement**

The critical role of fasteners (bolts, nuts, and washers) play in ensuring safe and reliable solar photovoltaic (PV) structures (trackers, canopies, and racks) is underappreciated. Each fastener connects two or more components to create a fastened joint (a.k.a. bolted joint) that transmits static loads (live, dead, and snow) and dynamic loads (wind) and, in some systems, a low-resistance electrical ground path. A typical solar PV structure contains thousands of bolted joints, underscoring their vital role!

Unfortunately, fasteners are typically the weakest structural component in the racking system, and extreme cases can result in catastrophic structural failures.

In the author's opinion, bolted joint loosening is one of the most common and misunderstood joint failure mechanisms and an underlying cause of many structural reliability issues affecting the solar PV industry today.

If the broader goal of lowering LCOE is to be achieved, bolted joint loosening will need to be better addressed during the design, procurement, assembly, commissioning, and inspection of solar PV structures and joints.

## Repeated Joint Slip Results in Self-Loosening

**Explanation of Bolted Joint Self-Loosening**

- Approximately 90% of the energy expended to tighten the bolted joint is dissipated in heat, and 10% is stored as potential energy in the joint. (see Image 4)
- The potential energy will remain in the stored bolted joint if the friction in the threaded interface and under the rotating bearing interface is high enough to resist the un-winding tendency.
- Researchers in other industries have definitively proven that self-loosening is triggered when the interface under the bolt or nut head experiences a full slip which momentarily reduces the friction coefficients allowing an incremental release of energy from the bolted joint (incremental counterclockwise rotation). (Image 5)
- Repeated, fully reversing slip of the bolt head or nut creates a hysteresis loop and an accumulation of counterclockwise rotations over time. (Image 6)
- Unless a proven locking device is used, the clamp load in self-loosening bolted joints can drop to zero.

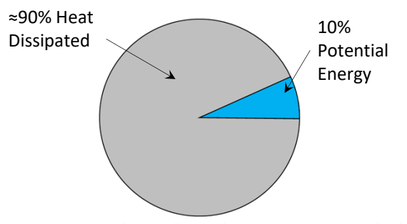


**Image 4:** Where does the Energy Expended to Tighten a Bolted Joint Go?

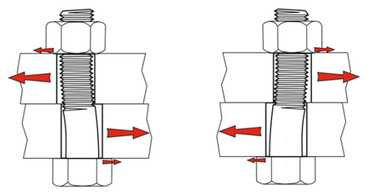

**Image 5:** Self-Loosening is Triggered by Repeated Joint Slip
*Image courtesy of Bolt Science, LTD*

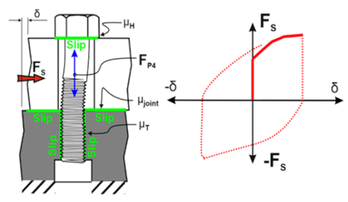


**Image 6:** Repeated & Fully Reversing Slip Results in Hysteresis Loop
*Image courtesy of Bolt Science, LTD*

QR Code to a video showing self-loosening in slow motion:

## Repeated Bolted Joint Slip Results in Loosening Due to Fretting Wear

**Explanation of Fretting Wear in Bolted Joints**

- Although appearing to be smooth surfaces, the load-bearing surfaces of a bolted joint contain many asperities. (see Image 1)
- When a bolted joint is assembled (tightened), the asperities on the load-bearing surfaces embed into one another and lock the two surfaces together, enabling it to transmit shear load.
- If the shear load is too high, the friction between the embedded load-bearing surfaces is overcome, and the joints are forced to slide past one another.

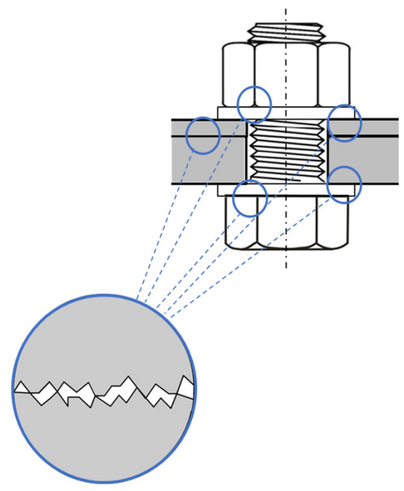

**Image 1**: Idealized Magnified Sketch of Load Bearing Surfaces
*Image courtesy of Bolt Science, LTD*

- The relative sliding action of the loading bearing surfaces results in fretting wear at the interfaces and an incremental loss of clamp load each time the joint slips. (Image 2)

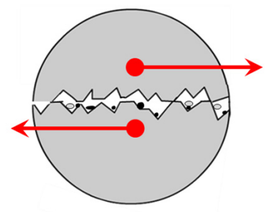

**Image 2:** Relative Sliding Results in Fretting Wear

- Factors such as the slip amplitude, the magnitude of the clamp load, and coating mechanical properties affect the amount of clamp load lost during each slip cycle.
- The total accumulated clamp load lost depends on the number of slip cycles. Additional research is required in this area. (Image 3)

**Image 3:** Example of Fretting Wear Of G90 Purlin at Joint Interface Due to Repeated Joint Slip

## Addressing the Common Root Cause of Bolted Joint Loosening

**The Root Cause of Bolted Joint Loosening**

The understanding of bolted joint reliability has evolved, it is now generally well-understood, and as a result, the design and assembly of reliable, cost-effective, fastened joints are commonplace in the steel construction, automotive, and off-highway industries!

**The common root cause of bolted joint loosening is repeated joint slip and/or separation.**

The key to reliable bolted joints is to develop and maintain a high clamp load in the joint such that the joint does not slip or open under the applied loads. Unfortunately, this is easier said than done.

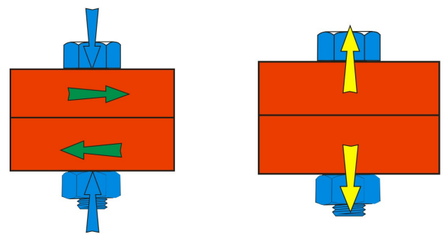

**Image 7:** The Key to Maintenance Free and Reliable Bolted Joints is Pretension
*Image courtesy of Bolt Science, LTD*

The solar PV industry is in its infancy compared to other industries; as a result, best practices, codes, and standards are not mature and do not yet assure structural reliability. At the same time, the industry faces intense cost pressures and demand.

A SETO Funded Research Program currently underway is focused on solar PV joint reliability. Topics being addressed in this project are;

- Characterizing known solar PV joint failures
- Identifying gaps in current codes and standards related to solar PV joints.
- Reliability mapping of the solar PV industry
- Development of simplified modeling techniques to characterize joint loading over the life of the system
- Laboratory testing of archetype solar PV joint to characterize capacity.
- Development of a guidance document.

**Web site:** https://so.lbl.gov/solar-pv-critical-fastened-joints

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QR Code for survey to share experiences & knowledge on solar pv bolted joint failures:

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