Understanding Locknut Performance Under Vibration

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Vibration-induced loosening of threaded fasteners is a persistent problem in engineering, product design, and construction. Failures from self-loosening can compromise safety, reduce reliability, and increase maintenance costs.

Threaded fasteners are widely used in manufacturing and construction operations due to their versatility and ease of installation. However, when under vibration, the relative motion between threads can cause gradual loosening, loss of preload, and eventual joint failure. While using conventional fasteners (alone or mated with washers) or adhesives provides some mitigation against the impact of high vibration, locknuts remain one of the most effective, cost-efficient, readily inspectable, and reliable solutions.

There are a number of benefits associated with locknuts. Some of the key benefits of locknuts include:

- Cost-effective, especially when compared with using multiple fasteners or lockbolts
- Resistant to the effects of vibration
- No special tools required for installation
- Broad selection of locknut types, allowing for the best match of locknut to the application
- Installation creates no deformation or damage to bolt integrity
- Proven in high-temperature and high-corrosive environments

Locknuts are specifically designed to counter the effects of vibration, and while numerous variations exist, they can be broadly grouped into three functional categories:

- Prevailing Torque Locknuts
- Free-Spinning Locknuts
- Structural Locknuts

This paper reviews how these three locknut types function, what materials and thread options are available, and how/where they can be effectively employed. It concludes with a set of frequently asked questions to aid in the selection of the most suitable locknut for various high-vibration environments.

Locknut Types

The three types of locknuts – **Prevailing Torque**, **Free-Spinning**, and **Structural** – combine to cover a wide range of high-vibration applications.

Prevailing Torque locknuts are designed to resist loosening by creating constant frictional resistance (prevailing torque) between their threads and the bolt. This frictional resistance can be achieved through the action of all-metal threads being deformed into bolt threads or, in the case of nylon-insert locknuts, where a polymer insert deforms into the bolt threads. Based on their installation process of deforming the locknut into the bolt threads, Prevailing Torque type locknuts are not designed to be loosened and reused.

Prevailing Torque locknuts are proven reliable in many high-vibration applications. In addition, these locknuts are available in many materials, enabling them to be used in a wide range of environments and conditions. Prevailing torque locknut options include:

- Distorted-thread locknuts feature a deformed or offset thread that creates friction against the mating bolt. Examples include nuts with a crimped or pinched section or an elliptical-shaped top.
- Top-lock nuts are designed with a deformed top section, often elliptical, that squeezes the bolt threads to create friction.
- Non-metallic insert locknuts use a nylon or polymer insert that expands and grips the bolt threads when tightened, creating friction and resistance to loosening.
- Centerlock nuts feature a deformed thread in the center of the nut that creates a prevailing torque lock.
- Stover nuts, an all-metal prevailing torque design, use a deformed thread to create locking action.
- Flex-type locknuts use various locking elements that deform to create locking action.

Free-Spinning locknuts are designed to spin freely during assembly until a clamp load is applied by tightening them against a bearing surface. Once tightened, these locknuts resist loosening. However, free-spinning locknuts can be removed and reused if required. There are a number of free-spinning locknut options, including:

- Nylon-insert locknuts feature a nylon ring or insert that deforms when tightened, creating friction against the bolt threads that prevents loosening. These designs are relatively easy to install and remove, but they are not as strong as all-metal locknuts.
- Jam nuts are thinner than standard nuts and are used in conjunction with a standard nut. The thinner nut is installed first, followed by the standard nut, which then jams the thinner nut against the surface, creating a locking action.
- Keps nuts feature an attached washer with serrations that bite into the bolt's mating surface when tightened, preventing loosening.
- Bearing locknuts are fully free-spinning until tightened, at which point their bearing surface is compressed into the bolt, creating a locking action.
- Flange nuts incorporate a flange (a wider, fully integrated washer) that distributes the clamping force over a larger area, enhancing stability and reducing the chance of accidental loosening.
- Serrated flange nuts, while similar to flange nuts, feature serrations on the underside of the flange that grip the mating surface, providing extra resistance to loosening.

Structural locknuts are designed to provide enhanced resistance to loosening in the most demanding applications, where sustained vibration and dynamic loading exist and structural integrity is critical. While standard locknuts offer significant resistance to loosening caused by vibration and torque, structural locknuts are engineered for reliable performance in high-stress, high-vibration applications where failure is not an option.

Structural locknuts, designed to withstand severe vibration and cyclic stresses, are crucial in many demanding applications, including aerospace, energy, and heavy equipment manufacturing, construction (bridges and buildings), and more.

Structural locknuts may use more advanced materials, including stainless steel or heat-resistant alloys, and specialized coatings (like galvanization) to enhance their corrosion resistance and performance in extreme environments. Examples of the use of these types of locknuts can include:

- Construction of steel structures and bridges, where locknuts are used to connect beams and columns, ensuring structural stability.
- Assembling aircraft engines and other structural components in aerospace applications, where high reliability and resistance to vibration are paramount.
- Locknuts are used in heavy machinery, like excavators and cranes, to provide stability against loosening under heavy loads and vibrations.

In essence, structural locknuts are a specialized class of locknuts built to withstand the most demanding applications and ensure the integrity of structures where safety and reliability are non-negotiable.

The quintessential structural locknut is the Lok-Mor® ANCO® PN-LOC®, an all-metal, self-locking nut. This industry-leading locknut features a stainless-steel ratchet pin coupled with a unique controlled lock indentation. The non-breakable ratchet pin limits damage to bolt threads and the removal of galvanizing during installation, while still providing reliably consistent locking torque.

Material Options

All locknuts are available in a wide range of materials and threading options to provide the best match of fastener to the application. Popular material options include:

- Carbon and alloy steels, which are both strong and cost-effective. However, these materials usually require some sort of coating for corrosion resistance.
- Stainless steel provides excellent corrosion resistance and is often used in marine and other corrosive environments. Stainless steel locknuts are significantly more than carbon or alloy steel versions.
- Non-ferrous alloys (brass, bronze, aluminum) are often selected based on specific conductivity requirements, corrosive conditions, or weight-saving demands.

Protective coatings, such as zinc, galvanization, cadmium, and other platings are often used to extend the service life of locknuts in corrosive environments.

High-Vibration Applications

There are many applications where the vibration-resistant performance of locknuts is critical to the safety, reliability, and life cycle of products and assemblies. Some key applications include:

- Automotive manufacturing, including suspension systems, wheel assemblies, and exhaust joints.
- Aerospace, where all-metal prevailing torque nuts are often specified based on their resistance to temperature extremes and vibration.
- Structural construction, including bridges, towers, and seismic applications.
- Railcar and heavy machinery, in which the “holding strength” of prevailing torque and structural nuts is proven to withstand the high-vibration demands associated with their application.
- The energy sector includes a number of demanding applications: wind turbines, power plants, solar panel installation, and various rotating machinery used in the oil and gas space. These applications can be well-served by the reliable “holding power” of structural, all-metal locknuts, which are proven to maintain their “grip” integrity over long service cycles.

Conclusion

For decades, locknuts have been proven reliably effective in maintaining joint integrity in a wide range of high-vibration connection applications. With the three categories of locknuts: **Prevailing-Torque, Free-Spinning, and Structural**, there is a locknut design that meets the performance requirements of most high-vibration applications, while also providing for easy installation and cost-effectiveness.

Frequently Asked Questions

Which locknuts perform best at high temperatures?

All-metal prevailing torque or structural locknuts are recommended, as nylon inserts soften under heat.

Do serrated flange nuts require washers?

No, the serrated flange eliminates the need for washers. However, the serrations' biting action may damage softer surfaces.

Can nylon-insert locknuts be reused?

Yes, free-spinning nylon-insert locknuts can be reused. However, non-loosening performance will decrease with each installation, since the nylon inserts will deform and eventually lose their holding capability.

When should structural locknuts be specified?

In safety-critical applications such as bridges, cranes, towers, rail cars, and heavy equipment, where fastener failure could compromise human safety.

What standards govern locknuts for high-vibration applications?

There are several key standards and certifications related to locknuts, including:

- **ISO (International Organization for Standardization):**
  - ISO 10511 for non-serrated locknuts
  - ISO 2320 for self-locking nuts
  - ISO 7040 for nylon insert locknuts
  - ISO 7042 for all-metal hex self-locking prevailing torque nuts
  - ISO 7044 for all-metal prevailing torque hex flange lock nuts
  - ISO 8641 (Aerospace) for self-locking nuts with a maximum operating temperature greater than 425 degrees C

- **ASME (American Society of Mechanical Engineers):**
  - ASME B18.16.6 (which replaced IFI 100/107) for prevailing torque locknuts (inch series), covering both all-metal and nylon-insert styles.
  - ASME B18.2.2 for dimensional specifications of heavy hex nuts, from which some locknuts are manufactured
- **ASTM International (American Society for Testing and Materials):**
  - ASTM A563 for carbon and alloy steel nuts, including locknuts
  - ASTM A194 for alloy and stainless-steel nuts, including those used in high-temperature or high-pressure applications
- **SAE (Society of Automotive Engineers):**
  - SAE ARP 1515B, SAE AS 4847B for general self-locking nut standards
  - Various SAE standards for specific types of self-locking nuts
  - Standards for nickel alloy, steel alloy, and iron alloy self-locking nuts
- **DIN (Deutsches Institut für Normung):**
  - DIN 980 for prevailing torque hex nuts
  - DIN 982 / DIN 985 for nylon insert hexagon stop lock nuts (equivalent to ISO 10511)

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