

# An Asymmetric Wrenching System with High Torque Transfer Capability for Aerospace Pins

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## ABSTRACT

The installation of common threaded aerospace fasteners by the application of a torque to a nut or collar is made possible by an internal wrenching element or recess feature adapted to the threaded end of a pin, which accepts a mating anti-rotation key designed to partially balance the applied torque. In applications such as the mechanical joining of composite structures accomplished by wet clearance fit installations of permanent fasteners, high nut or collar seating torques not adequately opposed by frictional resistance at the contact surfaces of the fastener and joint members effectively shift a greater proportion of the torque reaction requirement onto the recess and mating anti-rotation key which in turn can experience high torsional stresses exceeding their design capability and result in frequent service failures. In particular, the industry standard hexagonal recess and key have been shown to be highly susceptible to such severe conditions with failure rates as high as 20% in field applications. A superior asymmetric recess design was developed for use in aerospace pins to enhance the reaction torque capability of the fastener and mating key over the current baseline, without compromising established functional requirements, enabling fastener use in more demanding service applications. In this paper, the installation performance capability of threaded pins with the asymmetric recess is compared to equivalent substitutes with alternative recess designs through a series of standard industry tests conducted across a range of part sizes. Numerical simulations and experimental test results demonstrate that the asymmetric recess and key exceed the torsional strength and fatigue life of the current industry standard and other commercially available designs, offering the potential to increase productivity and reduce the cost of structural assembly and maintenance operations.

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## INTRODUCTION

Unlike bolts and screws that have wrenching features or recesses located on their heads, aerospace pins employ an anti-rotation recess located in their threaded extremities as wrenching feature, as depicted in [figure 1](#). This characteristic allows for a smooth, axisymmetric head that provides several advantages in terms of weight and aerodynamic performance.

The anti-rotation recess located on the threaded side of the pin also provides benefits for the assembling and fastening of structures, as a single tool can be used to provide torque and anti-rotation simultaneously [[5](#)].

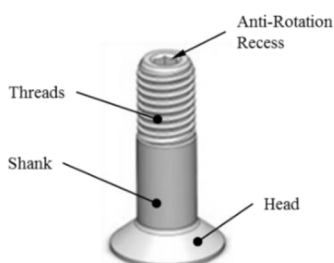


Figure 1. Typical aerospace pin with anti-rotation recess located on its threaded extremity.

Aerospace pins are normally intended for a single installation (no reusability) and can be made out of diverse materials, such as Titanium 6AL-4V, Nickel alloys and stainless steels, with different head configurations, thread lengths, finishes, and can be installed with various types of prevailing torque nuts and frangible collars [[7](#)].

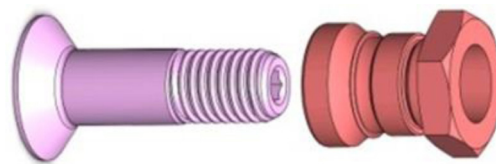


Figure 2. Aerospace pin with hex-recess mated with a frangible collar

## Fastener Installation

Aerospace pins are usually installed to carefully prescribed torque values in order to provide the intended preload [[4](#)]. For installing nuts, the torque control is provided by the installation tool, whereas frangible collars have a built-in break-off torque. Example of recommended seating torques for different sizes and nut materials are listed on [table 1](#).

Table 1. Example of seating torque values (lbf-in) for installing aerospace pins with nuts made of different materials

| Size  | Al 7075 | Ti 6AL-4V | A286    |
|-------|---------|-----------|---------|
| .1640 | 15-25   | 15-25     | 30-40   |
| .1900 | 25-35   | 30-40     | 40-50   |
| .2500 | 60-80   | 80-95     | 110-130 |
| .3125 | 130-160 | 150-200   | 200-250 |

These fasteners are often installed with special torque tools that have driving sockets with coaxial anti-rotation keys [6], as shown in figure 3.

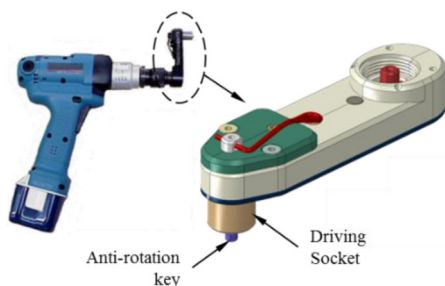


Figure 3. Installation tool gearhead with coaxial socket and anti-rotation key

During installation, as the driving socket engages the nut or collar and the anti-rotation key engages the pin recess, the torque acting upon the pin is shown in figure 4.

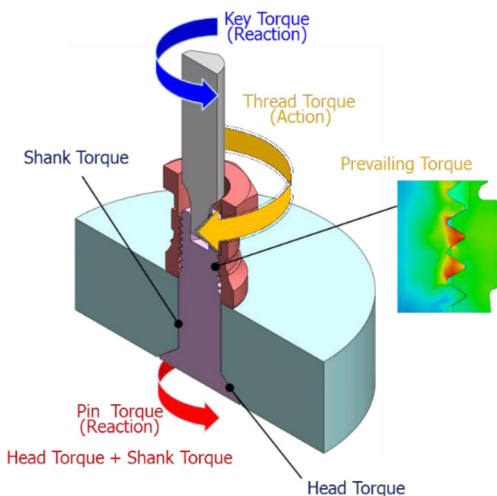


Figure 4. Torque acting on an aerospace pin during installation

The torque balance for the pin can be written as follows [3][4]:

$$T_T + T_P = T_H + T_S + T_K$$

Where  $T_T$  is the thread torque applied by thread engagement,  $T_P$  is the prevailing torque from the nut or collar,  $T_H$  is the reaction torque from head friction,  $T_S$  is the reaction torque from shank friction, and  $T_K$  is the anti-rotation key reaction torque.

Common aerospace pins system were designed and configured for use in metallic structures in interference fit conditions [1]. In such applications, most of the applied torque is absorbed in the pin shank and through head friction, with little or no torque being transferred to the anti-rotation key. For these applications, the widely adopted hex key has been successfully used for decades. However, as new

structural materials, such as composites, and different installation conditions are becoming more common [2], problems have been observed in many aircraft assembly lines around the world.

## TYPICAL INSTALLATION PROBLEMS

For clearance fit applications commonly found in composite structures, in the absence of shank friction, the reaction torque is shared between head friction and the anti-rotation key:

$$T_T + T_P = T_H + T_K$$

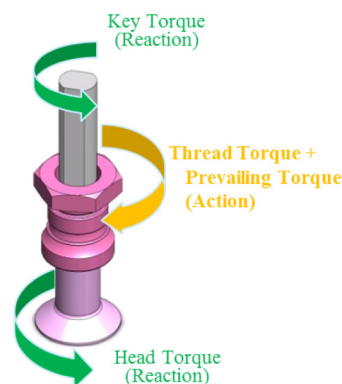


Figure 5. Torque balance for an aerospace pin installation in clearance fit condition

In this case, the combination of different factors can lead to key overloading and installation failures. The four main contributing factors for these installation problems are high prevailing torque, galling, low friction sealant, and improper tool operation.

### High Prevailing Torque

Nuts and collars used with aerospace pins are fitted with some form of anti-vibration feature that prevents them from loosening in service, especially in the absence of preload. The most common form of anti-vibration mechanism used is crimping, when a portion of the nut or collar threads is deformed around the circumference, generating impedance to rotation, in the form of prevailing torque.

When high strength materials are used in combination with finishes that produce significant friction, and the fastener threads are close to their maximum material conditions, a considerable amount of impedance and prevailing torque can be generated. The problem with high prevailing torque is that it can be generated in the absence of preload, before the nut or collar reaches the structure. In this case, there is no head friction and all torque applied to the system is equilibrated solely by the anti-rotation key. This condition can produce excessive key stresses, especially for commonly used configurations such as hex key, reducing fatigue life or even leading to sudden fracture.

### Galling

Certain combinations of fastener materials and finishes can be susceptible to galling during installation. If severe galling and complete seizing of a nut or collar happens before any preload is generated, all the applied torque is transferred directly to the anti-rotation key. Since the target installation torque is usually based

on the desired seating torque for a nut or collar, these torque values are much higher than the capability of typical anti-rotation keys, and a galling condition can lead to sudden key failure

### Low Friction Sealant

Some types of lightweight sealant used in composite applications, including the ones filled with hollow microspheres, have very low coefficients of friction. This condition affects the torque balance in clearance fit, as the capability of reacting torque through head friction becomes reduced by the low friction. In dry installations, without sealant, the fastener head tends to absorb about 70% of the applied torque through friction, leaving the remaining 30% for the anti-rotation key. In wet, low friction conditions, this balance can be reverted, leading to key overloading, as shown in [figure 6](#).

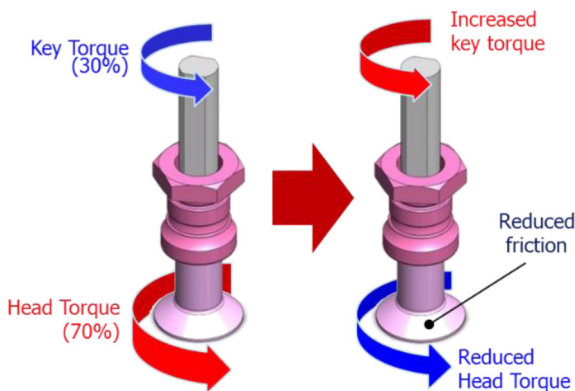


Figure 6. Torque balance for an aerospace pin installed in clearance fit in dry condition (left) and with low friction sealant (right)

Depending on the types of fasteners being installed, repeated and continuous overloading can lead to a very low endurance life for the anti-rotation keys, with some manufacturers reporting key failures in up to 20% of installations.

### Improper Tool Operation

Another source of anti-rotation key overload is through improper tool operation. In the situation where the nut or collar is approaching its fully seated position, just before collar break off or tool clutch activation, all the torque generated from the tool has to be equilibrated by the operator's hands. At this moment, if the operator lets the tool rotate freely but keeps the tool active, the nut will stop spinning around the pin, and the tool will start spinning around the driving socket. When that happens, the totality of tool torque generated has to be equilibrated by the key. In other words, it is possible to overload the anti-rotation key with the full seating torque of the system in every installation, by just letting the tool turn freely. As the labor force in aerospace assembly lines tends to be very skilled, this condition is not very common, but considering operator fatigue and tight production schedules as factors, it is not difficult to imagine that this form of overloading can be observed throughout the industry.

### Typical Key/Recess Failure Modes

When overloading occurs to the anti-rotation key/recess, the most common failure modes observed are: twisted key, fractured key, round-off key, and cam-out recess. These failure modes can be associated to two basic key/recess characteristics, torsional and bearing strength.

Twisted key, as depicted in [figure 7](#), occurs when the material of the key is ductile enough to endure large plastic deformation in torsion.

Depending on the severity, this deformation may prevent proper key engagement.



Figure 7. Twisted hex key

Key fracture is observed when the overloading produces a sudden failure or rupture. This failure mode is usually combined with fatigue, when a crack is propagated during regular use, gradually reducing the torsional strength, ultimately fracturing during an overload condition. This failure mode is also observed when the key is made out of brittle, low toughness materials. [Figure 8](#) shows an example of hex key fracture.



Figure 8. Fractured hex key

Key rounding-off is a gradual process that particularly occurs when there is clearance in the engagement between a key and its mating recesses. As the offset between key and recess profiles increases, the bearing area between them becomes very small, degenerating line contact. This is particularly prominent in keys with hexagonal configuration, where the bearing stresses are concentrated on edges at the hex vertices, deforming and rounding them. A hex key with round-off edges is shown in [picture 9](#).