Tough Titanium Fasteners

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A line of fasteners made of a titanium alloy that provides high strength and toughness has been developed for aerospace and Formula One race car applications. Called Aerlite 761, the new alloy is based on an existing beta titanium alloy that conforms to the chemistry requirements of AMS 4958 (3Al-8V-6Cr-4Zr-4Mo). Although conventional AMS 4958 cannot provide the required mix of fastener properties, newly developed, proprietary processing techniques enable Aerlite to meet the strength and toughness needed for these critical fasteners.

- *Aerlite 160*: The optimized alloy made possible the development of tension bolts called Aerlite 160. Twelve-point/flanged Aerlite 160 bolts are capable of maintaining 1100 MPa (160 ksi) tensile and 655 MPa (95 ksi) shear strength in diameters from 0.75 through 1.125 inches. (SPS engineers estimate that the alloy will allow the manufacture of bolts up to 1.5 inch diameter.) The bolts meet the requirements of industry titanium bolt specifications such as NAS 621, NAS 4004, AS 7460, and AS 7461. These bolts also match the fatigue performance of the smaller-diameter Ti-6Al-4V fasteners.
- *Aerlite 180:* Another fastener product, Aerlite 180, has been developed for minimum tensile strengths of 1240 MPa (180 ksi) and shear strengths of 745 MPa (108 ksi). Many alloy-steel and corrosion-resistant-alloy fasteners exhibit these strength levels, but traditional Ti-6Al-4V fasteners simply cannot match them. However, Aerlite 761 easily meets these strength requirements in tension-rated twelve-point/flanged fasteners with diameters through one inch.
- *Aerlite 200:* A fastener called Aerlite 200 was designed for cylinder head studs and suspension bolts in race-car engines. During alloy development, engineers in the high-performance racing industry approached SPS for higher-strength titanium fasteners to replace heavier components. The European thread specifications to which these parts are manufactured utilize thread-area conventions that produce the calculated fastener strengths of 1400 MPa (200 ksi).

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Titanium alloy fasteners that provide high strength and toughness have been developed for aerospace and automotive applications.

Fatigue strength

The fatigue strength of aerospace fasteners is typically characterized by their ability to achieve an average of 65,000 cycles when tested under R = 0.1 conditions. (R is the ratio of the minimum fatigue load to the maximum fatigue load). Another convention is to define the maximum fatigue load as a percentage of the bolt's ultimate tensile strength.

The fatigue strength of high-performance racing fasteners is typically characterized by their ability to achieve a high number of cycles (i.e. 2.5 million) when tested under high mean-load conditions. Often, the data cited is the maximum alternating stress parts can withstand to provide the above cycle-life at the stated mean load.

The table presents the minimum tensile, shear, and fatigue properties for the Aerlite 160, 180, and 200 fastener products. ■

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Conventional titanium fasteners

Titanium fasteners weigh approximately 40% less than steel or corrosion-resistant alloy parts. The incentive to exploit this obvious advantage is high. However, many titanium alloys exhibit characteristics that make them unsuitable for certain fastener applications. Because of the inherent limitations of existing titanium alloys, engineers often must choose between lighter weight and higher performance when specifying fasteners for critical aerospace and racing applications.

The majority of titanium-alloy fasteners are manufactured from the industry workhorse titanium alloy, Ti-6Al-4V (AMS 4967), but these fasteners have size and strength limitations. For instance, tension-rated Ti-6Al-4V bolts up to 0.75 in. diameter meet the strength requirements of aerospace bolt specifications. However, larger-diameter parts from this alloy must be downgraded in strength, because it is not possible to heat-treat thick sections of this material to full strength. (This is similar to how hardenability limits component size in heat-treated steels.) In addition, attempting to push Ti-6Al-4V components to higher strength levels produces serious brittleness problems.

Some titanium alloys can be heat-treated to higher strength levels and maintain their full strength in larger size parts. However, serious issues with formability, notch sensitivity, and property scatter limit their potential for fastener applications. Historically, designers have been forced to select heavier steel or corrosion-resistant alloy parts when larger fastener diameters or higher strength levels were required, forsaking the lightweight benefits of titanium.

Minimum mechanical properties of Aerlite fasteners

Minimum properties	Aerlite 160	Aerlite 180	Aerlite 200
Tensile strength, ksi (MPa)	160 (1103)	180 (1241)	200 (1400)
Shear strength, ksi (MPa)	95 (655)	108 (745)	108 (745)
Fatigue strength: σ_{max} (% of UTS) for 65,000 cycles at R=0.1	40	38	37
Alt. stress for 2.5 MM cycles at σ_{mean} 65% UTS	—	—	~ ± 4.35 ksi (~ ± 30 MPa)

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