



Outlook on New Materials and Technologies for Automotive Fasteners

汽车紧固件新材料及技术展望

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1. The Development of Automotive Fasteners

The position of China's automotive fasteners in the global automotive industry is attributable to the rapid growth of China's fastener sector. As the market shifts from an incremental market to a saturated market, the fastener industry faces increasingly stringent requirements, necessitating capabilities in systematic R&D, modular design, and specialized production. As automobile sales continue to grow, public attention toward the automotive industry has shifted from a focus on brand and scale to an equal emphasis on vehicle quality, performance, brand, and scale; the accelerated development of fasteners for new energy vehicles has become a strategic priority. Currently, the primary automotive joining methods include welding, riveting, bolting, and adhesive bonding, with bolting remaining the dominant method. In new energy vehicles, high-strength bolts are primarily used in battery module connections, body structure connections, and motor & controller connections. This is mainly because high-strength bolts offer high strength (with high tensile and yield strengths, capable of maintaining connection stability in harsh environments to ensure the safe operation of critical components), excellent corrosion resistance (capable of long-term use in humid and corrosive environments without failure, thereby extending service life), and safety (the use of high-strength bolts significantly enhances overall vehicle safety and reduces safety incidents caused by loosening or failure of connected components).

2. New Materials for Automotive Fasteners

There is a wide variety of lightweight materials used in the automotive industry, each with its own advantages and limitations. Currently, the fastener industry for new energy vehicles is rapidly advancing toward the combined use of multiple materials, ensuring that the right material is used in the right place. This article discusses the development of new material technologies for automotive fasteners—including non-quenched and tempered steel, cold-headed forged stainless steel wire rod, aluminum alloy bolts, and automotive ultra-high-strength bolts—and offers insights into potential challenges ahead.

2.1 Non-quenched and Tempered Steel

In recent years, **non-quenched and tempered steels from the two major alloy systems—V-Nb and V-Nb-B-Ti—have been gaining attention and are undergoing trial implementation in relevant fields.** PATAC, Shanghai University, and Nanjing Iron and Steel Group, among others, have jointly developed Grade 8.8 M6×840 and M6×930 long studs for securing EV battery packs. These studs utilize a non-quenched and tempered steel (MLF20MnVNb) solution that eliminates the need for quenching and tempering. The matrix features a ferritic-bainitic dual-phase microstructure. By incorporating a stabilized aging treatment process, the studs achieve a yield-to-tensile strength ratio of 1:0.8



and excellent strength-to-toughness properties. They meet the requirement of straightness within 0.5 mm/m, resolving the challenge of heat treatment deformation in slender bolts, and thus hold significant potential for widespread adoption.

Xingcheng Special Steel has successfully developed high-uniformity Grade 8.8 non-quenched and tempered fastener steel using the XDWP (water bath) process. The steel exhibits excellent uniformity in tensile strength across the entire coil (≤ 20 MPa), with stable and reliable product performance that aligns with low-carbon, environmentally friendly, and green manufacturing principles; Zenith Steel Group has successfully developed non-quenched and tempered cold-headed steel wire rod for mass production. It is currently being applied in both Grade 8.8 and Grade 9.8 strength grades, while the company is also intensifying R&D efforts on Grade 10.9 non-quenched and tempered cold-headed steel. In recent years, Henan Jiyuan Iron Steel (Group) has developed energy-saving non-quenched and tempered cold-headed steel grades SCN430 and SCN435, which do not require heat treatment and have been used in Grade 8.8 high-strength bolt products. However, practical experience has shown that **the use of non-quenched and tempered steel in high-strength fasteners still presents issues with die wear.**

2.2 Cold-headed Stainless Steel Wire Rod

Some fasteners used in new energy vehicles are made of duplex (austenitic-ferritic) stainless steel grades. These steels feature a matrix composed of both austenitic and ferritic phases (with the less abundant phase constituting at least 25% of the total) that are magnetizable, and are typically strengthened through cold working. In terms of performance, duplex stainless steel not only retains the excellent toughness and weldability of austenitic stainless steel, but also offers the high strength and other advantages of ferritic stainless steel.

The composition and microstructure of stainless steel play a critical role in its susceptibility to stress corrosion cracking (SCC). Austenitic stainless steels are prone to SCC in chloride solutions, whereas ferritic stainless steels exhibit better resistance to SCC. The smaller the ferritic grain size, the better the resistance to SCC; therefore, **duplex stainless steels possess high resistance to chloride-induced SCC, with a stress corrosion cracking threshold approximately three times that of austenitic stainless steels.** In Cr-Ni stainless steels, the ratio of ferritic to austenitic phases in the solid solution is commonly calculated and evaluated using “chromium equivalent” and “nickel equivalent.” **Duplex stainless steel eliminates the risk of SCC in austenitic stainless steel under chloride stress corrosion, particularly in cases of stress corrosion cracking induced by pitting corrosion.** Therefore, duplex stainless steel is widely used in many applications involving chloride stress corrosion. In new energy vehicles, however, heat-resistant stainless steel is still used for high-temperature applications or high-temperature fasteners. Depending on the material type and heat treatment process, ML06Cr15Ni25Ti2MoAlVB steel bolts, after solution treatment at 980–990°C followed by aging at 700–720°C for 16 hours, exhibit an austenitic + MC (dispersed carbide) microstructure, with a tensile strength (Rm) exceeding 1100 MPa.

2.3 Aluminum Alloy Bolts

In the context of lightweighting for new energy vehicles, the design of magnesium alloy electric drive assembly housings must not only address the protection of the magnesium alloy itself but also utilize aluminum alloy bolts to prevent galvanic corrosion between the magnesium alloy housing and the fasteners. Consequently, the extensive use of aluminum alloy bolts is unavoidable, including for the connection of aluminum stamped parts, castings, and extrusions.

The primary mechanical properties of bolts made from 6061 aluminum alloy for automotive applications, following the appropriate manufacturing processes—particularly solution heat treatment and aging—are as follows: tensile strength $R_m \geq 150$ MPa; yield strength $R_{p0.2} \geq 120$ MPa; elongation after fracture $A \geq 7\%$. Testing of actual bolts and screws shows a wedge load of $R_m \geq 140$ MPa; for bolts or screws that cannot undergo tensile testing, a minimum breaking torque test is applicable. These material properties are achieved through appropriate forming and heat treatment processes; At temperatures above 540–560°C, bolts shall undergo at least one homogenization solution annealing and aging hardening treatment. After cold forming, the heat treatment and artificial aging process must be performed in a continuous furnace. Following heat treatment, thread rolling is performed, and finally, deep cryogenic treatment is applied to enhance the mechanical properties of the aluminum alloy.

7075 aluminum alloy bars were heat-treated in a roller-hearth quenching furnace. They underwent solution quenching at $465 \pm 5^\circ\text{C}$ for 2 to 6 hours, followed by tension straightening within 12 hours of the solution quenching, with a tension ratio set at $2.0 \pm 0.3\%$. The aging process was conducted at $120 \pm 3^\circ\text{C}$ for 24–25 hours, followed by mechanical property testing. The results are shown in **Table 1**. The mechanical property test results of the specimens all meet the requirements of Grade 4.8 in the GB/T 3098.1 standard; the tensile strength is 60–80 MPa higher than the standard requirement, the stress at non-proportional elongation is 80–100 MPa higher than the standard requirement, and the elongation is also higher than the standard requirement. Furthermore, when different heat treatment processes were applied to 7075 aluminum alloys with diameters ≤ 12 mm, their mechanical properties all met the standard requirements.

Table 1. Results of Mechanical Property Testing on 7075 Aluminum Alloy Bars After Heat Treatment

Test No. and Technical Standards	Tensile Strength/MPa	Non-proportional Elongation Strength $R_{p0.2}$ /MPa
GB/T3098.1	≥ 420	≥ 340
2400101	496~505	433~449
2400102	483~500	435~442
2400103	489~502	439~450
2400201	478~485	429~438
2400202	481~492	437~443
2400203	476~487	428~439
2400301	480~493	434~438
2400302	479~489	438~445
2400303	470~482	424~434

Current issues in the application of aluminum alloy bolts include calculation of the engagement length between aluminum alloy bolts and magnesium alloy housings; selection of surface treatments for aluminum alloy bolts; and development of torque-angle assembly



processes. Topics requiring further research are ① Surface treatment for aluminum alloy bolts typically involves lubrication; when selecting a surface treatment (or anodizing), the effect of the sealing medium must also be taken into account. ② Through torque failure testing, design requirements for the engagement length of aluminum alloy bolts are established, and process parameters for torque-angle are determined.

2.4 Ultra-high-strength Bolts for Automobiles

Automotive ultra-high-strength bolt technology is based on VDA 235-205 (high-strength and ultra-high-strength fasteners with bainitic heat treatment for the automotive industry, performance grades 12.8U to 16.8U). According to GB/T 3098.1, the performance grades range from 10.9 to 12.9, featuring a quenched martensitic microstructure (high-strength bolts); according to VDA 235-205, the performance grades range from 12.8U to 16.8U, with technical requirements as shown in **Table 2**, featuring a bainitic microstructure obtained through isothermal quenching (ultra-high-strength bolts).

In the R&D of bolts, alloyed steel and heat treatment are prioritized. The technical approach for the subsequent thread rolling process involves stricter technical requirements for raw materials than those specified in national standards, and SAE 4140 steel is used. Bolt manufacturing process: Spheroidizing annealing → Drawing → Spheroidizing annealing → Drawing → Cold heading → Deburring → Turning → Heat treatment → Rounded corner enhancement → External cylindrical grinding

Table 2. Mechanical Property Requirements for 12.8U to 16.8U Grade Bolts

Test Items	Bolt Performance Grade						
	12.8U	12.9U	14.8U	14.9U	15.8U	15.9U	16.8U
Level Indicator	12.8U	12.9U	14.8U	14.9U	15.8U	15.9U	16.8U
Rm (min.)	1220		1400		1500		1600
Tensile Strength Rm (max.)	1370		1550		1650		1750
Yield Strength Rm (min.)	98	1100	1120	1260	1200	1350	1280
Elongation After Fracture A5% (min.)	12		10		9		8
Cross-sectional Reduction Ratio Z% (min.)	52		50		48		44
Vickers Hardness HV10 (min.)	380		425		455		480
Vickers Hardness HV10 (max.)	430		475		505		530
Wedge Load Angle	6/4						
Rated Load	870	970	985	1110	1050	1185	1115



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Figure 1: Schematic Diagram of Subframe Mounting Bolts and Installation Locations

→ Thread rolling → Surface finishing. Tolerance control requirements for high-strength vehicle bolts are particularly stringent: the outer diameter must be within ± 0.02 mm, and the major diameter tolerance for the threaded section must be within ± 0.010 mm. Key process points: ① Ensure that raw materials undergo annealing with zero carbon gain and no decarburization; ② Use high-precision multi-station cold heading machines to prevent excessive deviations in opposite sides and major diameter during forming, controlling them within ± 0.02 mm. Since the thread rolling process is performed after heat treatment, it is essential to completely avoid issues such as bending of the bolt shank. Specialized

equipment has been added, including a centerless grinder for the external diameter (major diameter) grinding process; ③ To meet Grade 6g thread precision requirements, high-precision thread rolling machines for M12–M24 sizes, high-precision thread rolling dies, and inspection equipment such as contour profilometers and projection projectors have been added; ④ Ensure that the defect rate (PPM) for delivered batches is <60 . As is well known, the failure of high-strength bolts is primarily due to fatigue. According to EN standards, specific fatigue life requirements are established for high-strength bolts used in vehicles: no fractures or cracks shall occur under cyclic loading at frequencies greater than 80 Hz. The fatigue life for Grade 12.8U is specified to be no less than 4.5×10^6 cycles; and the fatigue life of Grade 14.8U must be no less than 5×10^6 cycles. After the completion of prototype production, at least 15 units from each batch are required for type testing. The results of the pilot production inspection and the mechanical property tests of the bolts are shown in Table 3. Following the crash test, none of the rear mounting bolts on the subframe fractured, and the battery pack remained undamaged; the crash test results were satisfactory.

Table 3. Test Results for the Mechanical Properties of Bolts

Test Items	Technical Requirements	Test Results	Determination Result
Tensile Strength Rm, (MPa)	1400~1550	1535, 1524, 1509, 1525, 1521, 1493, 1507, 1536	OK
Yield Strength Rm, (MPa)	≥ 1120	1264, 1266, 1260, 1276, 1270, 1255, 1249, 1272	OK
Elongation After Fracture A5, (%)	≥ 50	51, 50, 51.5	OK
Cross-sectional Reduction Ratio Z, (%)	≥ 10	12, 10, 11.5	OK
Vickers Hardness HV10	425~475	462, 464, 467, 469, 452, 464, 462, 464	OK
Shear Force (NK)	≥ 115	118.5, 119, 118, 118, 117	OK
Fatigue Life (10,000 times) 80~130HZ	≥ 500	502, 667, 501, 1000, 1000	OK

At the end of last year, China General Machine Components Industry Association officially released T/TCMCA 0034-2025, “Grade 14.8–16.9 Ultra-High-Strength Fasteners: Bolts, Screws, and Studs” (published on November 24, 2025; effective December 25). This standard establishes, for the first time, unified technical specifications and acceptance criteria for Grade 14.8–16.9 ultra-high-strength bolts in China, filling a gap in China’s standards for high-end ultra-high-strength fasteners and marking a crucial step forward for China’s fastener industry on the path toward high-end development and domestic production. The new standard clearly defines the core criteria and scope of application for Grade 14.8–16.9 ultra-high-strength bolts, providing clear guidelines for industry production and application. By defining ultra-high-strength bolts as those with a tensile strength of ≥ 1400 MPa, the standard clearly distinguishes them from traditional high-strength bolts, filling a gap in the definition of fasteners in the domestic ultra-high-strength grade. These bolts are suitable for ultra-high-strength connections and fastening in high-end sectors such as automotive, rail transit, wind power, engineering machinery, and machine tools, directly addressing the core needs of China’s high-end equipment manufacturing. The standard specifies an operating temperature range of -50°C to $+200^{\circ}\text{C}$ and recommends application in low-corrosion environments. It particularly emphasizes that the sensitivity of ultra-high-strength materials to hydrogen embrittlement increases with higher strength, laying the foundation for subsequent technical requirements and process specifications. See Figure 2 for a schematic installation diagram of bolts for new energy vehicles.

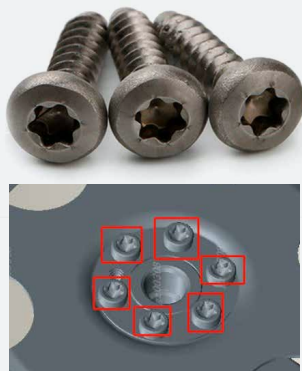


Figure 2. The schematic installation diagram of bolts for new energy vehicles

3. Conclusions

The increasing speeds of new energy vehicles, the trend toward lighter components, the shift toward higher-power drive systems, and improvements in braking and current collection performance all necessitate the simultaneous advancement of materials and processing technologies for high-strength fasteners. Consequently, extensive R&D to ensure reliability is essential. During the R&D phase for automotive fasteners, building upon the development and refinement of new materials, it is essential to advance structural design, manufacturing, and testing technologies to ensure that fastener functions are highly compatible with and integrated into the vehicle as a whole. Only through continuous transformation and upgrade can automotive fastener companies achieve long-term development. ■