ZT68-600MPa Al-Mg High-Strength Bolt

I. Preface: Connection Technology Bottlenecks Under the NEV Lightweighting Wave
Driven by the dual-carbon policy and automotive energy consumption regulations, lightweighting has become the core development direction for new energy vehicles. According to the Energy-Saving and New Energy Vehicle Technology Roadmap 2.0 and the new GB 36980.1-2025 electricity consumption limit standards, vehicle weight reduction delivers clear quantitative benefits:

For NEVs, every 100kg weight reduction increases range by 6%–8%;

For ICE vehicles, every 100kg weight reduction lowers fuel consumption by 6%–8% and extends tire life by 7%;

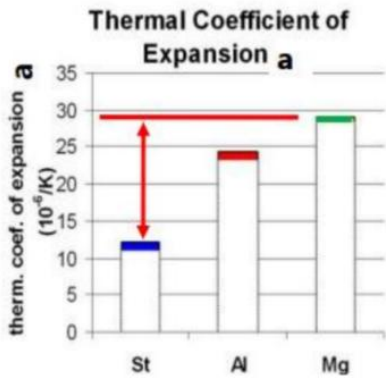
Excise tax policies also favor lightweighting—for ICE vehicles, every 100kg weight reduction lowers the tax rate by 0.85%.

The lightweighting material evolution path is clear:
Vehicle bodies are transitioning from traditional single-material steel to multi-material composites including aluminum alloy, magnesium alloy, and carbon fiber. Chassis and three-electric system components are increasingly adopting magnesium alloy die-cast parts. Magnesium alloy is the lowest-density material among current engineering structural metals, with theoretical weight reduction of 30%–35%. Its application scenarios have expanded from dry-area interior small parts such as steering wheel frames and instrument panels to core three-electric wet-area components including battery trays and electric drive housings.
However, after large-scale deployment of magnesium alloys in vehicles, traditional steel fasteners have exposed two critical connection pain points:
Pain Point 1: Galvanic Corrosion Between Dissimilar Metals

Electomotive Series

Material	Voltage	
Magnesium	-2.34	Most Anodic
Aluminum	-1.67	
Zinc	-0.76	
Cast Iron/Steel	-0.44	
Brasses	-0.28	
Tin	-0.14	
Lead	-0.13	
Hydrogen	0.00	
Copper	+0.34	
Silver	+0.86	
Graphite (Carbon)	+0.86	
Platinum	+0.90	
Gold	+1.36	Most Cathodic

Magnesium has an electrode potential as low as -1.6V, while ordinary carbon steel bolts have a potential of only -0.44V. The substantial potential difference forms a galvanic cell in humid environments, with the magnesium matrix acting as the anode and corroding rapidly, resulting in white rust, thread degradation, housing spalling, and leakage failures.
Pain Point 2: Preload Loss Caused by Thermal Expansion Coefficient Mismatch



Magnesium alloy has a thermal expansion coefficient of 26×10^{-6}℃$^{-1}$, while ordinary steel has only 12×10^{-6}℃$^{-1}$—a difference of more than double. Under vehicle thermal cycling conditions, the deformation mismatch between bolts and magnesium housings causes continuous preload loss over long-term use, leading to bolt loosening, seal failure, and structural noise.
The industry's current compromise solution is the 420MPa-class 6056 aluminum alloy bolt (AL9 Alu 6056). While it alleviates corrosion and thermal expansion issues to some extent, its strength ceiling is limited by cold-forging mass production constraints, making it incapable of meeting the high-torque, high-load connection requirements of three-electric structural components. This has become a core technological bottleneck hindering the implementation of magnesium alloy lightweighting.
Addressing this industry gap, Toprecision ZCJ, leveraging over 20 years of fastener R&D and manufacturing expertise, has independently developed the ZT68-600MPa cold-forged high-strength 7-series modified aluminum alloy bolt. This product breaks through the existing strength bottleneck of aluminum bolts, perfectly suits the connection needs of NEV magnesium alloy and aluminum alloy lightweight components, and provides a lightweight, highly reliable, long-life integrated fastening solution.

II. Corporate R&D and Manufacturing Capabilities
Toprecision ZCJ is an innovation-leading enterprise in China's fastener industry, with full industry-chain R&D, mass production, and quality inspection capabilities, providing solid support for ZT68 product commercialization:

Industry Layout: Shenzhen headquarters + Xiangyang automotive-dedicated production base + dual overseas factories in India and Indonesia, enabling global delivery; monthly fastener production of 500 million units, serving over 100 OEM and parts customers worldwide;

Certifications & Technological Accumulation: Obtained IATF16949 automotive industry quality certification in 2013, formally entered the NEV supply chain in 2017, and holds 26 effective fastener patents; in 2025, mastered the cold-forging process for ZT68 high-strength aluminum alloy bolts, with sample testing achieving tensile strength up to 630MPa and a nominal stable strength rating of 600MPa;

Full In-House Production: Self-established complete production lines including tooling development, multi-station cold forging, thread rolling, machining, heat treatment, surface treatment, automatic assembly, and optical sorting—no outsourcing required, with full quality control throughout;

Comprehensive Precision Testing Laboratory: Equipped with metallurgical microscopes, Brinell/Vickers hardness testers, 2D profile projectors, universal tensile testing machines, friction coefficient testers, spectrometers, constant temperature and humidity chambers, coating thickness gauges, ROHS detectors, and other full testing equipment. All mechanical, corrosion, and thermal stability tests can be completed in-house.

III. Performance Limitations of Mainstream Industry Aluminum Bolts

The current mainstream mass-produced aluminum alloy bolt in the industry is the 6056 (AL9 Alu 6056) 420MPa-class. Material parameters: EN AW 6056 (AlSi1MgCuMn), density 2.7 g/cm³, elastic modulus 69,000 MPa, linear thermal expansion coefficient 23×10^{-6}℃$^{-1}$; lower yield strength limit 350MPa, tensile strength 400–440MPa, elongation after fracture ≥6%, maximum long-term service temperature 150°C.

Due to cold-forging mass production process limitations, this product has a low strength ceiling, and under high-load, thermal-cycling conditions in NEV three-electric systems, it suffers from insufficient load-bearing capacity—a long-standing pain point in industry lightweighting connections.

IV. ZT68 Core Technological Breakthroughs: Comprehensive Performance Upgrade Over 6056 Aluminum Bolts

1. Tensile Strength Test

ZT68 7-series modified vs. external hexagon flange bolt M8×40

Five parallel samples tested. Measured average maximum tensile force: 23,030.66N; average tensile strength: 629.25MPa; average yield strength: 510.20MPa; average elongation: 8.21%. Sample strength values were stable within 628–630MPa with minimal data scatter, demonstrating excellent batch-to-batch consistency.

Sample	Stress Cross-Sectional Area mm²	Max Force (Fbc) N	Tensile Strength (Rm) MPa	Yield Strength (Rp0.2) MPa	Yield Ratio	Elongation Af, %
Sample 1	36.6	22,997.92	628.36	524.2	0.83	8.29
Sample 2	36.6	23,046.27	629.68	521.57	0.83	8.02
Sample 3	36.6	23,020.37	628.97	502.59	0.80	8.22

Sample 4	36.6	23,060.81	630.08	498.26	0.79	8.22
Sample 5	36.6	23,027.95	629.18	504.37	0.80	8.31
Average	36.6	23,030.66	629.25	510.2	0.81	8.21

Performance Indicator	ZT68 600MPa-Class High-Strength Al Bolt	Industry Mainstream 6056 (AL9) 420MPa Al Bolt	Performance Improvement
Tensile Strength Rm	~630MPa	~420MPa	~ +50%
Yield Strength Rp0.2	~500MPa	~350MPa	~ +43%
Yield Ratio	~0.8	~0.85	Better ductility reserve
Elongation	≥8%	≥6%	Higher strength with maintained toughness

2. Head 6° Wedge Strength Limit Test

Simulating assembly impact and head load limit conditions. All 5 samples fractured in the unengaged thread section, with no head cracking or chipping. Cold-forged bonding strength between head and shank meets vehicle safety design standards. Sample ultimate tensile force range: 22.95KN–23.4KN, corresponding tensile strength 627MPa–639MPa.

No.	Nominal Stress Area mm²	Wedge Angle	Max Force Fm (KN)	Tensile Strength Rm (MPa)	Fracture Location
Sample 1	36.6	6°	23.15	633	Within unengaged thread length
Sample 2	36.6	6°	23.05	630	Within unengaged thread length
Sample 3	36.6	6°	23.15	633	Within unengaged thread length
Sample	36.6	6°	22.95	627	Within unengaged

4					thread length
Sample 5	36.6	6°	23.40	639	Within unengaged thread length

3. Hardness Uniformity Test

Ten parallel samples showed Vickers HV hardness values stably within 201–209, with small fluctuation range. No local soft or hard spots within the material, uniform microstructure, effectively avoiding localized stress concentration fracture risks.

No.	D1	D2	HV
Sample 1	29.908	30.549	202.949
Sample 2	29.695	30.122	207.321
Sample 3	31.404	29.267	201.522
Sample 4	29.054	30.549	208.810
Sample 5	30.763	28.840	208.810
Sample 6	30.549	29.267	207.321
Sample 7	30.763	29.481	204.391
Sample 8	30.122	30.336	202.949
Sample 9	30.336	29.481	207.321
Sample 10	30.122	29.481	208.810

4. Failure Torque Test

All five samples achieved failure torque values stably above 25N·m with low data scatter, demonstrating excellent assembly torque consistency suitable for automated tightening operations.

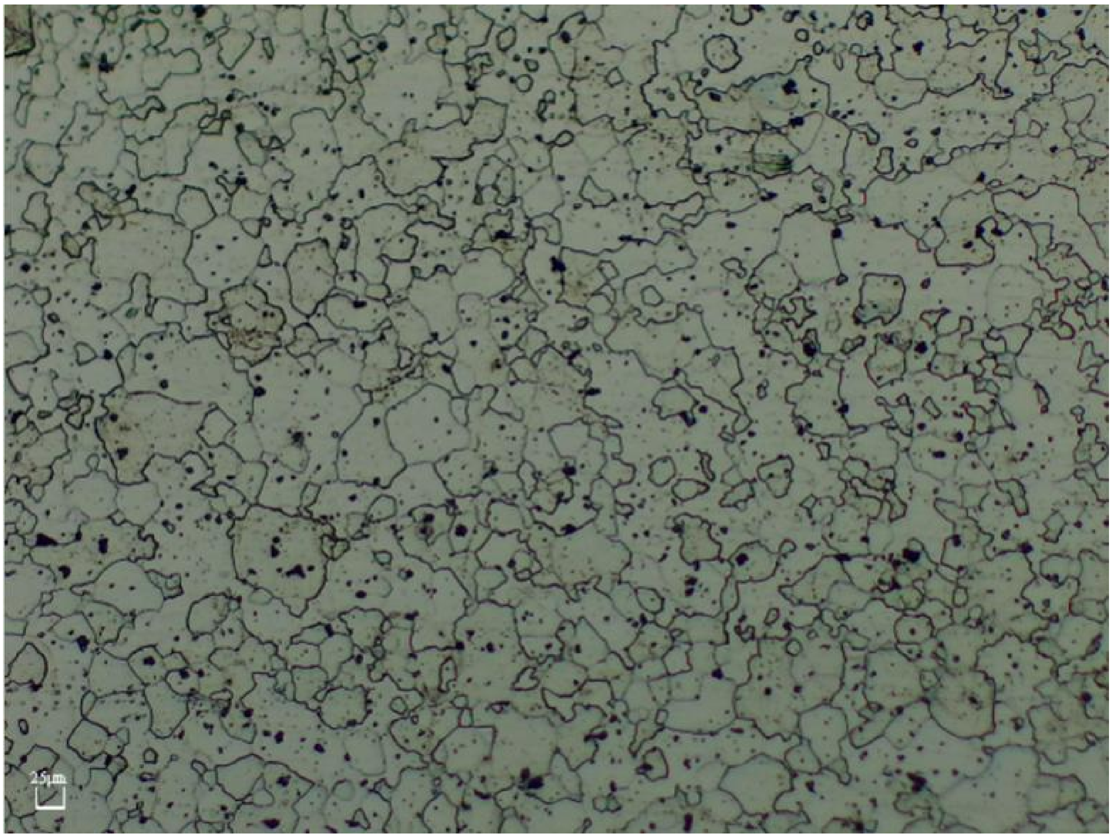
No.	Thread Spec	Pitch mm	Minimum Failure Torque Mbmin, N·m
Sample 1	M8×35	1.25	25.2
Sample 2	M8×35	1.25	25.2
Sample 3	M8×35	1.25	25.5
Sample 4	M8×35	1.25	25.3
Sample 5	M8×35	1.25	25.6

5. Microstructure Metallography: Foundation for High Strength and Toughness

Through high-precision metallographic examination, the ZT68 modified 7-series aluminum alloy microstructure exhibits two key advantages:

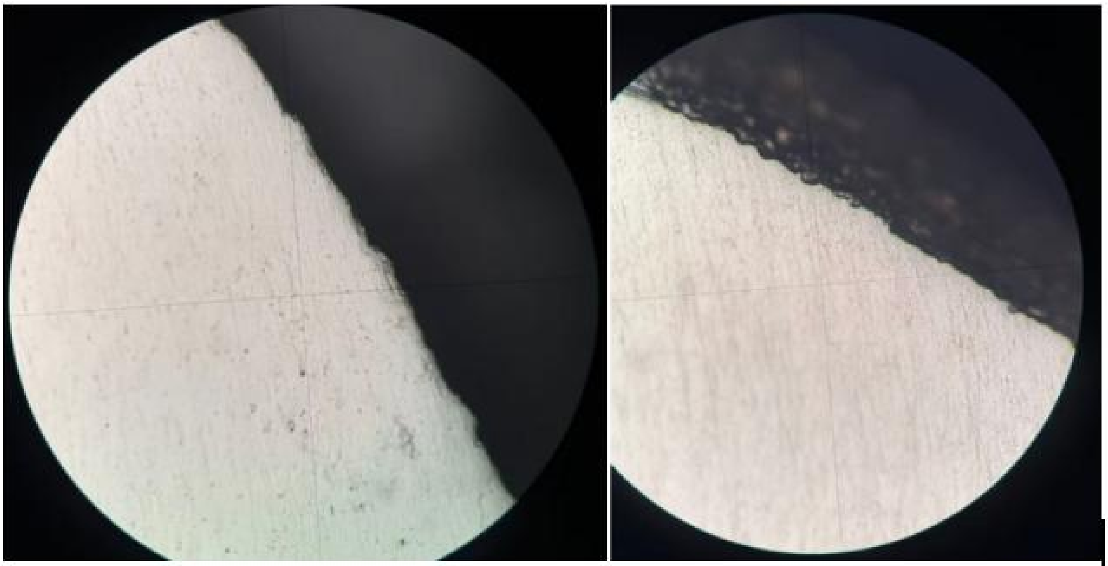
Fine and uniform grain structure with no coarse precipitated phases, effectively dispersing stress and significantly improving bolt strength and fatigue toughness;

Clean grain boundaries free of continuous brittle impurities (AlFe, AlSiFe phases), blocking corrosion medium penetration channels and enhancing long-term corrosion resistance at the microscopic level.



6. Intergranular Corrosion Resistance

After intergranular corrosion testing, ZT68 samples showed no intergranular corrosion grooves, no grain separation, and no deep corrosion channels. Corrosion was limited to superficial mild pitting, with no exfoliation corrosion, no penetrating intergranular corrosion, or other critical failure modes—suitable for battery packs, electric drives, and other humid/wet operating conditions.



7. Neutral Salt Spray Durability Test

Uncoated bare aluminum bolts: extensive white rust appeared after just 3 days of continuous salt spray.

ZT68 with anodized surface treatment: stably passed 60 days of continuous neutral salt spray testing, with no obvious surface corrosion marks—long-term corrosion protection suitable for vehicle service life requirements.

Uncoated surface

Anodized surface

8. Galvanic Corrosion Test with Magnesium Alloy
Using magnesium alloy AZ91 as the pairing reference, galvanic corrosion risk ranking: carbon steel > 7-series ZT68 > 6056 aluminum bolt.
ZT68 has an extremely small potential difference with magnesium alloy, generating virtually no galvanic corrosion driving force when used together, fundamentally solving the matrix corrosion problem of steel-magnesium pairings.

9. Controlled Friction Coefficient Surface Treatment System for Automated High-Precision Assembly
Addressing the stringent torque accuracy requirements of NEV automated tightening production lines, ZT68 offers tiered surface treatment and lubrication solutions for precise control of thread friction coefficient. All data based on M8×40 flange bolt measurements:

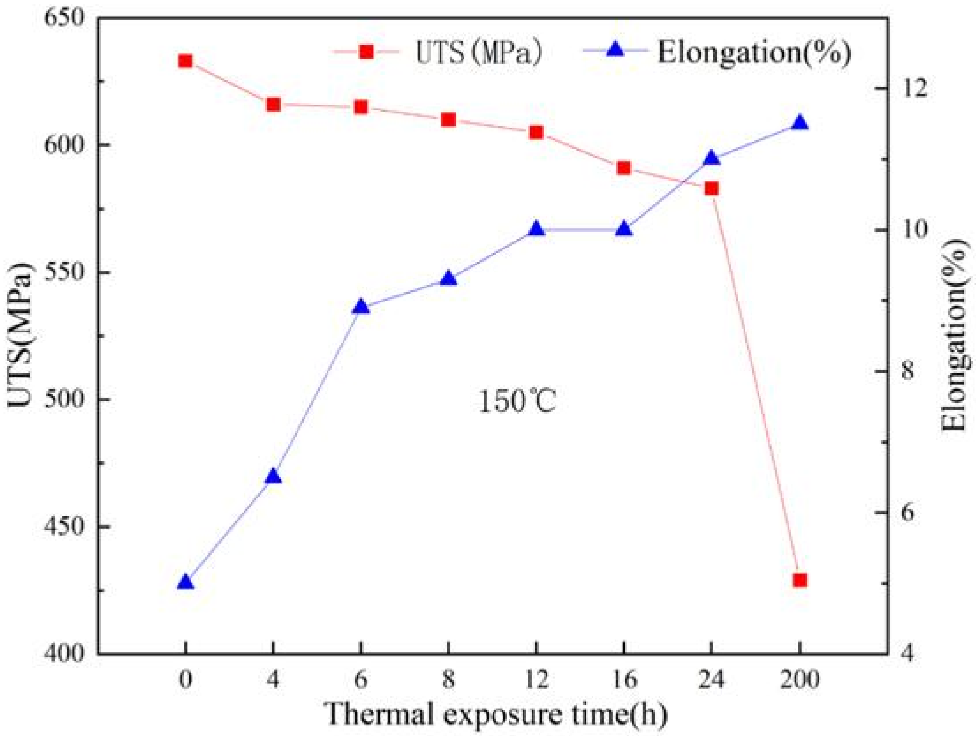
Surface Condition	Torque Coefficient K	Total Friction Coefficient μtot	Thread Friction μth
Untreated	0.343	0.286	0.186
Anodized	0.263	0.214	0.174
Lubricant No.1	0.256	0.208	0.147
Lubricant No.1	0.252	0.205	0.143
Lubricant No.1	0.253	0.205	0.148
Lubricant No.1	0.249	0.201	0.146

Lubricant No.2	0.145	0.108	0.083
Lubricant No.2	0.140	0.103	0.086
Lubricant No.2	0.146	0.109	0.075
Lubricant No.2	0.148	0.110	0.076
Lubricant No.3	0.135	0.099	0.072
Lubricant No.3	0.121	0.086	0.079
Lubricant No.3	0.135	0.099	0.072

The complete lubrication system can stably control total friction coefficient within the 0.09–0.15 range, with low tightening torque scatter and precise, controllable preload.

10. High-Temperature Thermal Stability

After 12 hours of continuous thermal exposure at 150°C, ZT68 bolts maintained tensile strength above 600MPa with elongation remaining around 10%. No significant strength degradation or creep relaxation under long-term high-temperature conditions—suitable for motor housings, electronic control assemblies, and other components operating under sustained high temperatures.



ZT68 aluminum alloy has thermal expansion coefficient and elastic modulus close to those of magnesium alloy. Under thermal cycling, the bolt deforms in sync with the magnesium housing, significantly reducing preload decay rate, avoiding long-term loosening and leakage, and solving the persistent loosening problem of steel bolts.

V. ZT68 Cold-Forging Manufacturing Process Route

ZT68 breaks through the industry barrier that traditionally prevented aluminum alloys from being cold-forged into high-strength bolts. Complete process chain:

Core process highlights: Through precise control of Mg, Zn, and Cu strengthening phase precipitation, combined with gradient cooling solution treatment, both ultra-high strength and good ductility are achieved simultaneously after cold forging. Compared with purely machined fasteners, the cold-forging process offers higher production efficiency, lower cost, and superior thread fatigue strength over cut-thread fasteners.

VI. Typical Application Scenarios for ZT68-600MPa Cold-Forged High-Strength Aluminum Alloy Bolts

ZT68-600MPa cold-forged high-strength aluminum alloy bolts are specifically designed for NEV magnesium alloy and aluminum alloy lightweight components, covering three-electric systems, chassis core wet areas, and thermal cycling applications:

NEV Electric Drive Systems: Magnesium alloy motor housings, reducer flanges, electronic control housing fastening;

Traction Battery Packs: Magnesium alloy battery trays, casing frames, cold plate connections;

Lightweight Chassis Components: Aluminum/magnesium alloy control arms, steering knuckles, subframe lightweight connections;

Large Magnesium Alloy Die-Cast Structural Connections for vehicle interior and exterior trim.

VII. Comprehensive Core Advantages Summary of ZT68-600MPa Cold-Forged High-Strength Aluminum Alloy Bolts

Lightweighting Advantage: Aluminum density of only 2.7g/cm³—same-spec bolts weigh significantly less than steel, reducing vehicle curb weight in volume applications;

Reduced Galvanic Corrosion Risk with Magnesium Alloys: Potential matched with magnesium substrate, mitigating dissimilar metal corrosion issues;

Thermal Expansion Matching for Long-Term Preload Stability: Preload decay under thermal cycling far lower than steel bolts, improving sealing reliability;

Industry-Leading Cold-Forged Strength: 50% increase in tensile strength over mainstream 420MPa aluminum bolts, greatly enhanced load capacity;

Strength-Toughness Balance for Fracture and Fatigue Resistance: Yield strength exceeding 500MPa with elongation ≥8%, suitable for long-term vehicle vibration conditions;

Long-Term Corrosion Protection for Wet Areas: Anodized treatment stably passes 60-day neutral salt spray, with excellent intergranular corrosion resistance;

Stable Service at 150°C: No significant strength degradation under long-term use in motor and electronic control high-temperature zones;

Precisely Controllable Friction Coefficient: Multi-tiered lubrication solutions match automated tightening lines with excellent torque consistency;

Fully Proprietary Cold-Forging Mass Production Process: Currently mature sample specification is M8×40 external hexagon flange bolt; additional specifications can be developed based on project requirements;

Complete Automotive-Grade Quality Control: Backed by IATF16949-certified facility with full in-house testing laboratory, completing full performance validation.

VIII. Corporate Support Services

Toprecision ZCJ Precision Hardware (Shenzhen) Co., Ltd., as the R&D and primary production base for ZT68, together with the Xiangyang automotive-dedicated plant and overseas factories in India and Indonesia, can simultaneously meet the delivery needs of both domestic OEMs and overseas NEV customers, providing full-process technical support from sample development, joint performance testing, small-batch trial production, to large-scale mass production.

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Xiangyang Automotive-Dedicated Production Plant
Company Name: ZCJ Metal Technology (Xiangyang) Co., Ltd.
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PT Top Precision Fastening Indonesia
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IX. Conclusion

As NEV magnesium alloy lightweighting scales up, traditional steel fasteners and low-strength 420MPa-class aluminum alloy bolts can no longer meet long-term vehicle reliability requirements. Toprecision ZCJ's ZT68-600MPa cold-forged high-strength aluminum alloy bolt, with its proprietary 7-series modified aluminum material, breakthrough cold-forging mass production process, and comprehensive mechanical and corrosion performance validation, solves the three major industry pain points in magnesium alloy component connections—corrosion, preload loss, and insufficient strength. It provides a highly reliable lightweight fastening connection solution for NEV lightweighting, facilitating the industrial-scale implementation of automotive lightweighting technology.