White Paper

3M™ Friction Shims for EV Battery Fixation

Calculations based on nearly two dozen battery packs show potential for OEM and tier design

Abstract

As electric vehicle (EV) production evolves, maintaining the structural integrity of the chassis is one of the most significant challenges facing automotive OEMs. In this paper, we address the performance of bolted joints where the EV battery pack – a significant source of weight – is affixed to the EV chassis. Using force, stress and static friction coefficient figures, we calculate the point of slippage and extrapolate the number of required fasteners in a theoretical model. We also explore the use of 3M Friction Shims and show their potential benefits, per bolt and for the fixation system as a whole. Our study demonstrated that 3M Friction Shims can increase coefficients of static friction up to 5 times, lessening or helping prevent slippage and enhancing overall fixation performance. 3M Friction Shims may also allow OEMs to use fewer and possibly standardized fasteners as well as streamline assembly and production time.

Background

The global wave of electric vehicle (EV) production brings new realities to engineers all across the spectrum of automotive design and production. Bolted connections and joints in electric vehicle, especially the chassis, must withstand greater amounts of shear as power from electric motors is available almost instantly during acceleration. At the same time, limiting curb weight is a significant challenge – battery packs can account for a significant percentage of the total vehicle weight. Slippage between the battery pack and chassis can cause vehicles to fail required crash test parameters.

In these scenarios, strengthening is required to vehicle chassis and especially battery fixation systems to handle the high shear force generated by high-mass battery packs. The mounting structure bearing the heaviest part of the vehicle requires many mechanical fasteners – which can add significantly to material sourcing and production processes. Therefore, battery fixation is a particular focus.

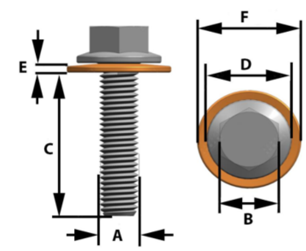
A solution

Mechanical fasteners – most commonly bolts – remain vital to vehicle assembly. 3M Friction Shims can help increase strength while maintaining or helping reduce the need for additional fasteners. A simple, lightweight solution for addressing potential failures of bolted joints due to loosening or fatigue, 3M Friction Shims can increase coefficients of static friction in automotive joints up to 5X, helping protect them from higher shear loads common in EV housing-to-housing and motor-to-chassis connections. Lower or no slippage also means less movement, which can help reduce noise, vibration and harshness (NVH).

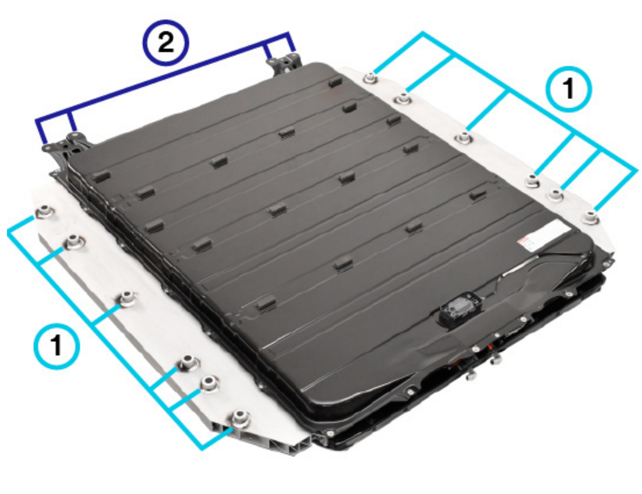
Method

3M conducted a series of force calculations on a scenario using 10 bolted connections in a theoretical EV battery fixation model. Your results may vary.

Battery pack weight = 313kgs
W = 1630mm
H = 180mm
D = 1770mm



Fastener 1	Fastener 2
A = 14	A = 12
B = 19	B = 19
C = 99	C = 31
D = 33	D = 32
E = 4	E = 3
F = 36	F = 36
Metric	Metric



Example battery pack. Source: Caresoft

3M engineers reviewed 20 current (MY 2002 and 2023) EV models from 19 OEMs and Tier 1s across China (40%), Europe (20%), and the US (40%). We specifically examined and recorded how the packs were affixed to the vehicle frame. Key factors considered were frame and battery pack substrates; number, locations and size of fasteners; weight per fastener; and total fastener weight.

Observations:

Automotive tiers manufactured three of the packs (~25%) while automotive OEMs manufactured the remainder. The average weight per fastener was 27 kg, including three "outliers" which used fasteners as heavy as 75 kg/fastener. Without these, the average weight/fastener was 22 kg. M12 or M10 bolts were used most frequently throughout the pack designs. Nearly all were Class 10.9 (SAE Grade 8).

Tiers averaged fewer fasteners per pack (14) vs. OEMs (24), and used the highest average weight per fastener (35 kg/fastener vs. 24 kg/fastener for OEMs).

All of the battery packs had side fasteners, but there were no obvious placement patterns for side, front or back fasteners. Thirty-five percent of the packs had no mid-pack fastening points. For packs made with modules, there is space for mid-pack fasteners to be threaded through the modules. As packs move more to cell-to-pack designs, without individual modules within the pack, it makes sense that only edge fastening points will be used. Two had only side fasteners, and on onethe aluminum pack was mounted to a steel frame which was then mounted to the vehicle chassis.

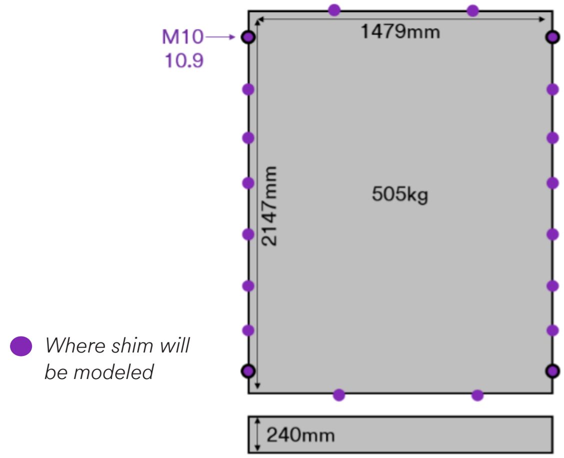
Majority of the manufacturers studied use lighter-weight aluminum for battery pack enclosures designed steel inserts within the aluminum. Steel is heavier, but it adds the necessary strength reinforcement (ultimate strength 460 MPa for steel[1] vs. 310MPa for aluminum[2]) at the points of attachment to the frame.

Sample battery fixation system

For purposes of the analysis, 3M developed a theoretical battery fixation system using a battery pack encompassing the most common features of the OEM packs examined. Your results may vary.

Key features:

- No mid pack fasteners
- Mean # of fasteners (20)
- Nominal bolt size M10, 10.9



This theoretical aluminum battery pack was affixed in a hanging configuration to a theoretical automotive chassis made of common e-coated steel. Note: For calculation, the pack was treated as a uniform box (in the real world, weight on packs is not distributed evenly and fastening strategies are determined with complex Structural Equation Modelling.)

Source: Caresoft

Boundary conditions

These conditions were established for battery fixation system calculations, including a typical OEM force requirement in case of an accident (up to 46G). For clarity, engineers assumed a pack weight of 750kg in a 10-bolt system. Your results may vary.

System (theoretical):
- Battery pack weight: 750kg
- Number of bolts: 10

Force:
- Acceleration force: 9.81 m/s2
- Theoretical OEM force requirement: 46G

Bolt pretension applied on the bolt surface:
- Preload (F_N): 58000 N (force in axial direction

Friction coefficients:
- Shim axial (side) surface and bolt: 0.15
- Other surfaces: 0.15

[1] *Cold rolled low carbon steel flat products for cold forming – Technical delivery conditions (DIN EN 10130)*
[2] *Aluminum and aluminum alloys – Extruded rod/bar, tube and profiles (DIN EN 755-2:2008)*

Calculations

(Your results may vary.)

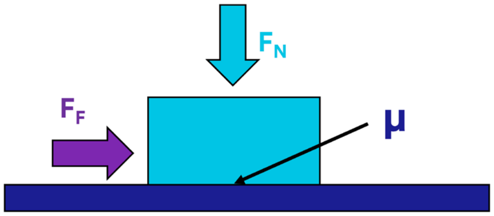
3M generated two sets of calculations based on 46G of force applied to:

a. 10-bolt system without 3M™ Friction Shims
b. 10-bolt system with 3M Friction Shims (4)

a. Battery fixation system without 3M Friction Shims

Again, we assumed a 10-bolt model using a M10/10.9 nominal bolt size.

750kg x 46 × 9,81m/s² = 340.000 N
F_N x μ = F_F



Battery pack weight (W):	750kg
Max force: (F):	46G
Acceleration (A):	9.81m/s²
Required friction force (F_F) per bolt (WxFxA):	34.0 N

Required friction force (F_F) per bolt :	34,000 N
Preload/max applicable normal force (F_N) per bolt (M10/10.9):	58,000 N
Coefficient of static friction (μ) w/o 3M Friction Shim:	0.15
Resulting friction force (F_F) per bolt (F_N x μ):	8,700 N
Total force (F_F) on battery pack (10 bolts):	87,000 N

Maximum applicable force (10 bolt system)

FF/(QxA); 87000/(750 × 09.81):	**11.8G (10 bolt)**
Connection slips at:	**12G**
Bolts required for 46G:	**39**

b. Battery fixation system with 3M Friction Shims

The identical calculations were performed using 3M Friction Shims, as follows:

Battery pack weight (W):	750kg
Max force: (F):	46G
Acceleration (A):	9.81m/s²
Required friction force (F_F) per bolt (WxFxA):	34,000 N

Preload/max applicable normal force (F_N) per bolt (M10/10.9):	58,000 N
Coefficient of static friction (μ) w/o Friction Shim:	**0.6 (was 0.15)**
Resulting friction force (F_F) per bolt (F_N x μ):	34,800 N
Total force (F_F) on battery pack (10 bolts):	348,000 N

With 3M™ Friction Shims:

Maximum applicable force (10 bolt system)	
FF/(QxA); 348000/(750 × 09,81):	**47G**
Connection slips at:	**Above 47G force**
Bolts required for 46G:	**10**

Conclusions

10-bolt system w/o 3M™ Friction Shims

Maximum applicable force 10 bolt	11,8G
Connection slips at:	12G
Bolts required for 46G:	39

10-bolt system w/ 3M™ Friction Shims

Maximum applicable force 10 bolt	47G
Connection slips at:	above 47
Bolts required for 46G:	10

By adding 3M Friction Shims, the number of additional bolts needed to help prevent slippage in a 10-bolt system drops from 29 to 0. This dramatic reduction in fasteners – while maintaining and even improving the fixation system strength – can help enable a more standardized fastening design which could carry over from model to model. All without adding any additional adhesives or impacting assembly/disassembly of the pack for future maintance needs.

About 3M Friction Shims

Engineers chose 3M Friction Shims for this battery fixation test. 3M Friction Shims are made from 0.1 mm ± 0.01 mm C60 steel with a layer of nickel phosphorous. Diamond particles are embedded across the flat surfaces of the shim at various particle sizes and surface concentrations. When placed between two mating surfaces in a bolted connection and applied with pressure, the diamonds "bite" into each surface to create a microform fit. This allows for a coefficient of static friction up to 5× greater than in a conventional bolted connection. Grade 55 3M Friction Shims were chosen for this test, featuring large 55 μm particles at 20-60% surface concentration.

3M™ Friction Shims fit within most engineering tolerances, allowing for lightweight, compact designs while increasing maximum load and peak torque in bolted connections. They can be used in a wide range of automotive applications, including:

- Shear joints in chassis applications
- Torsional joints
- Flange joints
- Joints with central bolt
- Bolted connections
- Fastener systems

3M Friction Shims are compatible with various mating surfaces such as aluminum, e-coated (cathodic-dip-coated) steel, painted and composite-material surfaces.

3M can conduct in-house testing to meet requirements. The company recently announced that it had produced and sold its 300 millionth 3M Friction Shim worldwide. For more information, scan the QR code or visit https://www.3m.com/3M/en_US/oem-tier-us/products/friction-shims/

3M Advanced Materials Division
3M Center
St. Paul, MN 55144 USA

Phone 1-800-367-8905
Web www.3M.com/frictionshims

3M Technical Ceramics
Zweigniederlassung der 3M Deutschland GmbH
Max-Schaidhauf-Str. 25, 87437 Kempten, Germany

Phone +49 (0)831 5618-0
Web www.3M.de/Technical-Ceramics