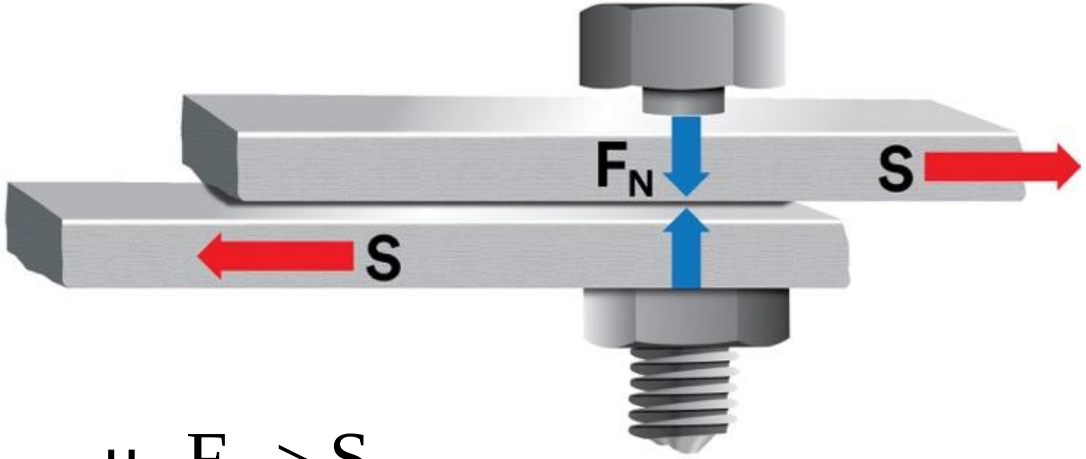
Science.
Applied to Life.™

# 3M™ Friction Shims in Robotic Applications

3M Advanced
Materials Division

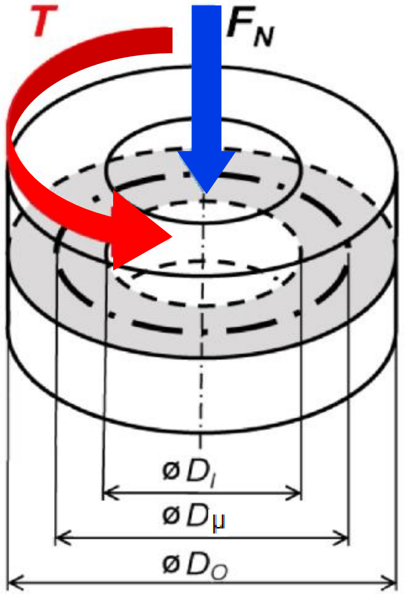
# Functional principle: Load transfer in bolted joints

1. **Shear Joint:** the applied loading is at right angles to the fastener axis




$$\mu \cdot F_N > S$$

2. **Rotating or Torque Joint**



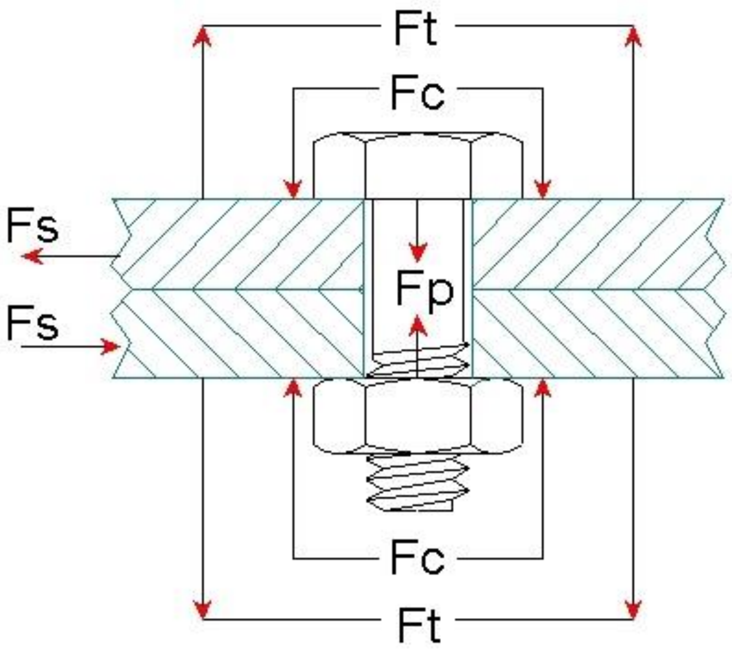

$$\mu \cdot \frac{D_\mu}{2} \cdot F_N > T$$

**Both types of joints require two factors: preload, or clamping force, and friction.**

# What is Preload?

- A critical component of designing bolted joints is not only determining the number of bolts, the size of them, and the placement of them but also determining the ***appropriate preload*** for the bolt and the torque that must be applied to achieve the desired preload.
- One key aspect to appreciate is that the root cause of the majority of bolt/joint failures is due to insufficient preload. It is unusual for the bolt to be overloaded. ***If the preload provided by the bolt is insufficient, joint separation and movement can occur, resulting in possible bolt fatigue and self-loosening issues***.

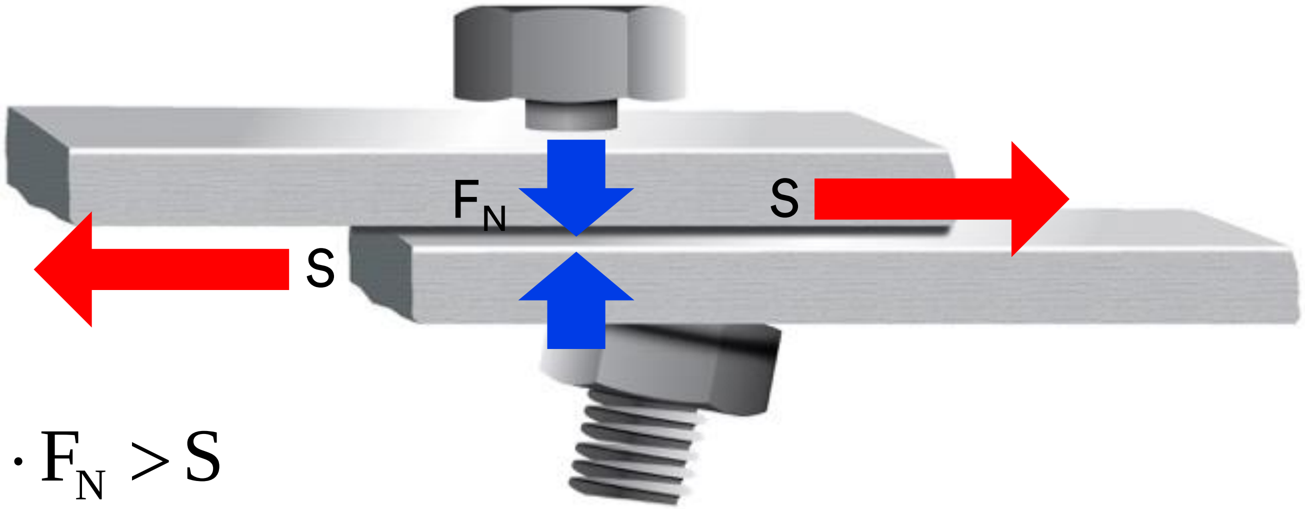
Most bolt/joint failures are ultimately caused by insufficient preload.




Fp = Preload Force
Fc = Clamping Force
Fs = Shear Force
Ft = Tension Force

# Problems that can occur in bolted joints

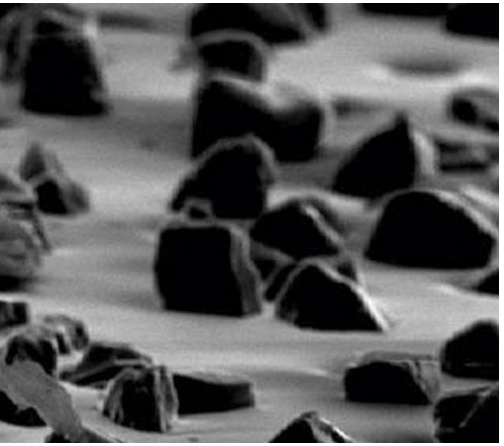
Too high shear force or insufficient preload can result in shear or failure



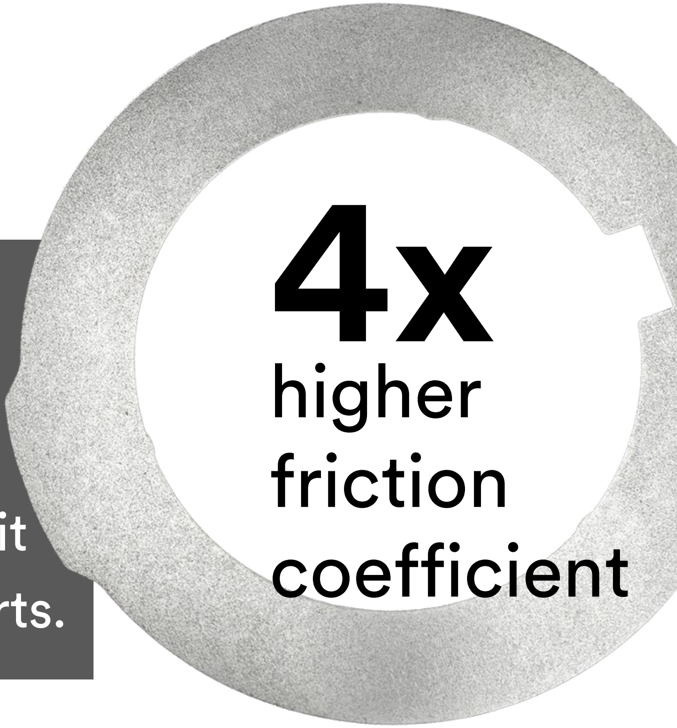

$$\mu \cdot F_N > S$$

# Get a grip with 3M™ Friction Shims.

- Increase coefficient of friction → transmit higher torque loads
- Reduce component weight → reduced moving masses
- Reduce risk of slippage → increase margin of safety
- Fit within narrow engineering tolerances → no design change required



3M™ Friction Shims consist of a coated steel shim with partially embedded diamonds. When the shim is placed between two components in a bolted connection, the diamonds “bite” into the surface, creating a microform fit and significantly increasing friction between the two parts.

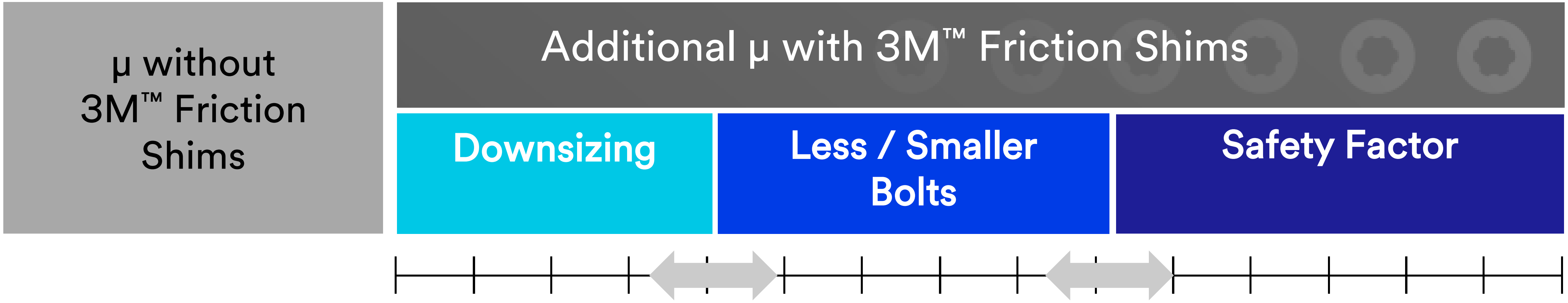


# Now, you have the power!

With 3M™ Friction Shims, you can reduce component size and increase performance – all while allowing a greater margin for safety.

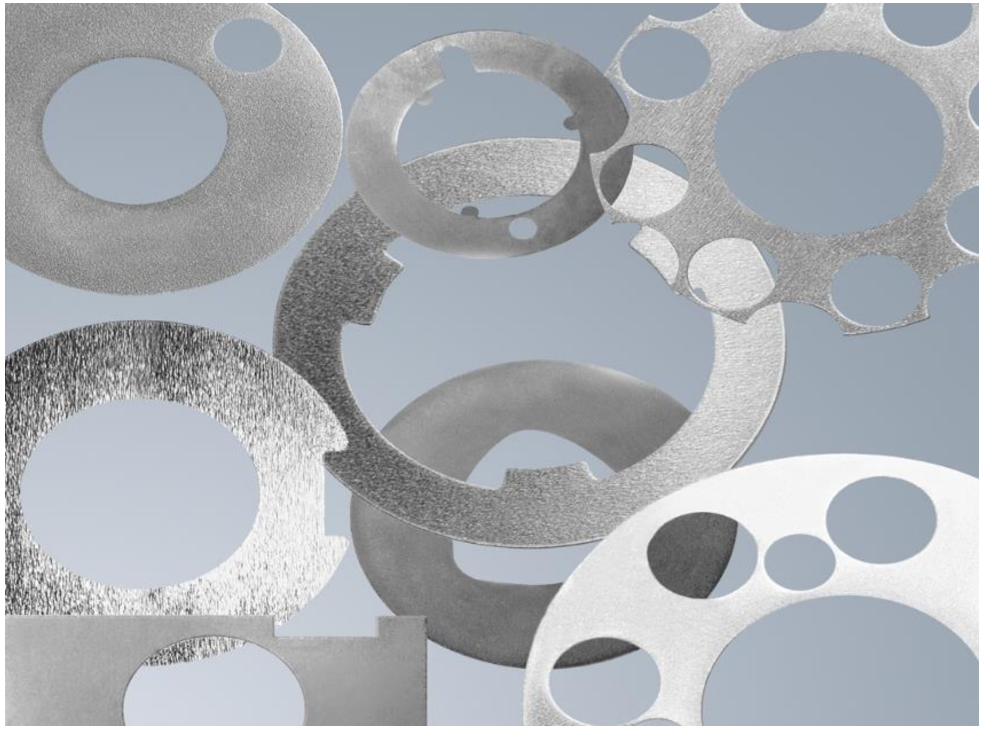
That gives you the freedom and flexibility you need to design lighter, transfer higher torque and reduce number or size of bolts.

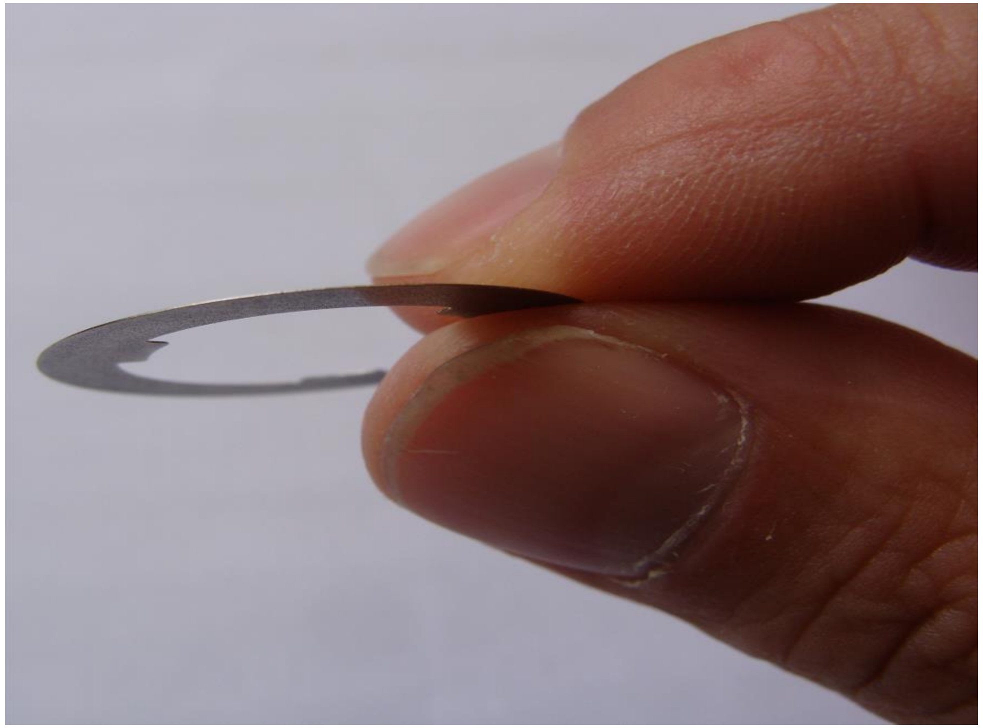
What can 3M Friction Shims do for you?



# Functional principle

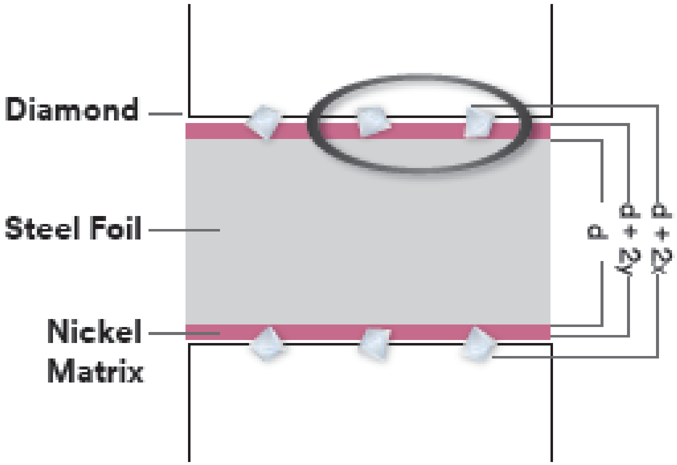
3M™ Friction Shims are thin steel foils with an electroless nickel / diamond coating

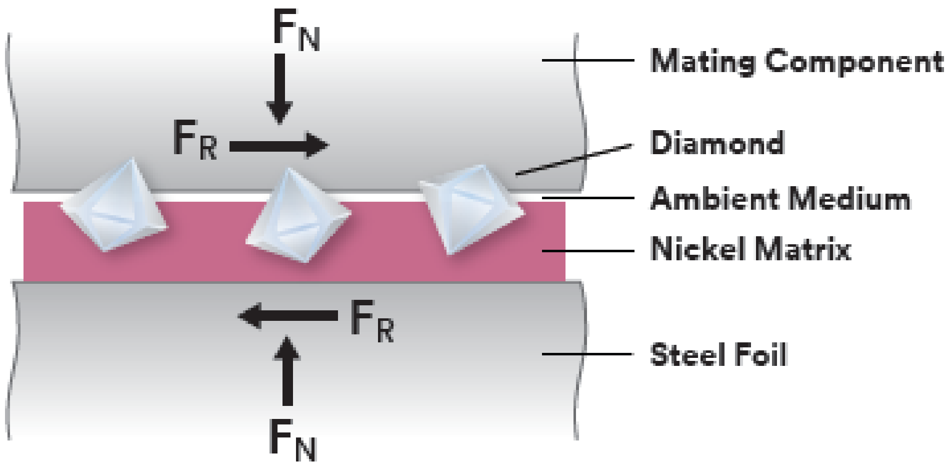




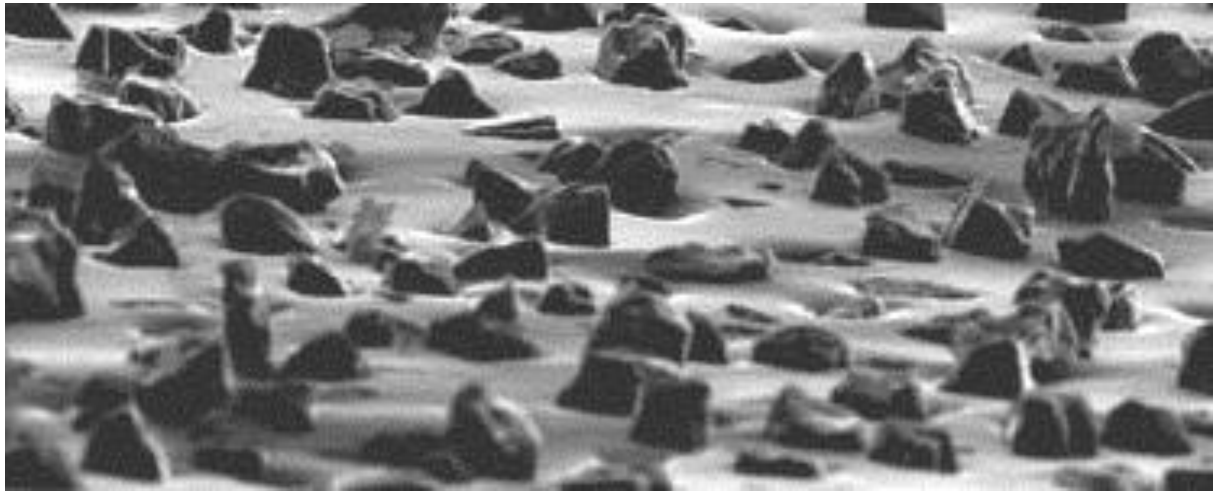
# Functional principle

**The microscale diamond interlocking results in an increase of the static friction coefficient up to a factor of 3 - 5 depending on the material combination, roughness and flatness.**

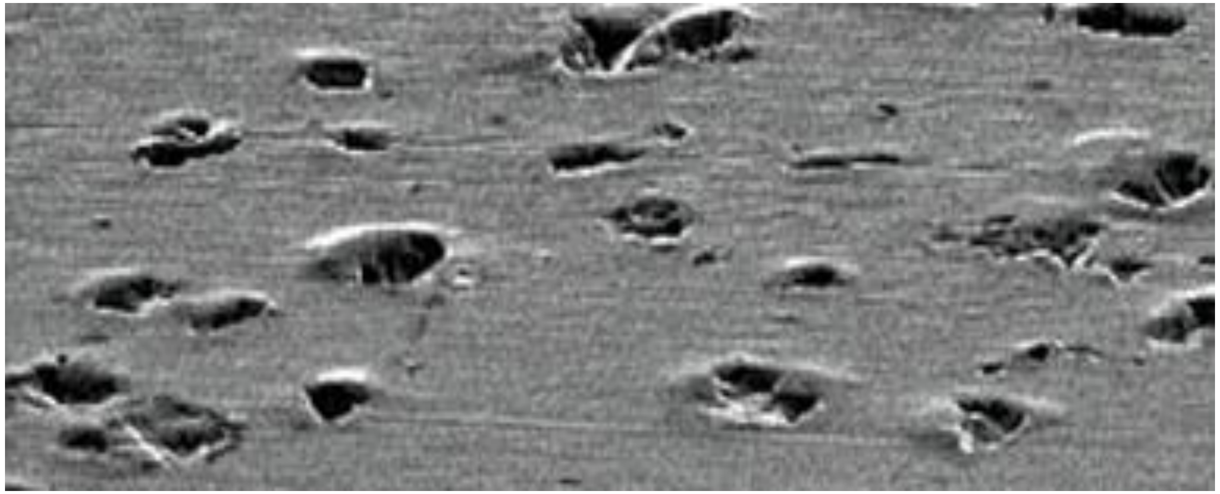


# Functional principle



Structure of 3M™ Friction Shim surface with diamonds embedded in nickel matrix



Mating surface after joining and disassembling

# Functional properties

| Functional properties | 3M™ Friction-increasing electroless nickel diamond coating | | |
|---|---|---|---|
| **Material properties*** | **Grade 10** | **Grade 25** | **Grade 35** |
| Delivery form | Coated Shim with Grade 10 | Coated Shim with Grade 25 | Coated Shim with Grade 35 |
| Color | Silver gray metallic | Silver gray metallic | Silver gray metallic |
| Shim material (preferably) | C75 S (acc. to EN10132-4) | C75 S (acc. to EN10132-4) | C75 S (acc. to EN10132-4) |
| Thickness d of shim | Standard 0.1 mm ± 0.01 mm (others upon request) | Standard 0.1 mm ± 0.01 mm (others upon request) | Standard 0.1 mm ± 0.01 mm (others upon request) |
| Base part processed by | Laser cutting or stamping | Laser cutting or stamping | Laser cutting or stamping |
| Matrix material | Electroless nickel phosphorus | Electroless nickel phosphorus | Electroless nickel phosphorus |
| Hard particle type | Diamond | Diamond | Diamond |
| Mean particle size | 10 µm | 25 µm | 35 µm |
| Avg. concentration of diamonds on the surface | 8 – 16 % | 8 – 25 % | 10 – 30 % |
| Hardness of nickel-phosphorus matrix | 400 – 600 HV 0.025 | 400 – 600 HV 0.025 | 400 – 600 HV 0.025 |
| Thickness of matrix x | 5 – 9 µm | 13 – 17 µm | 14 – 22 µm |
| Total layer thickness y | 10 – 20 µm | 25 – 35 µm | 35 – 50 µm |
| Total thickness of coated shim (based on uncoated shim 0.1 mm ± 0.01 mm) d+2 y | 0.13 mm ± 0.02 mm | 0.16 mm ± 0.02 mm | 0.185 mm ± 0.025 mm |

* Typical properties, not for specification purposes

# How to select the right grade->
# Depending on the roughness of mating surfaces


| | Roughness of mating surface |
|---|---|
| **Grade 10** | Rz **< 5.0 µm**, Ra < **1.0 µm** |
| **Grade 25** | Rz **< 12.5 µm**, Ra < **2.5 µm** |
| **Grade 35** | Rz **< 17.0 µm**, Ra < **3.5 µm** |

# 3M™ Friction Shims: Examples of coefficients of static friction

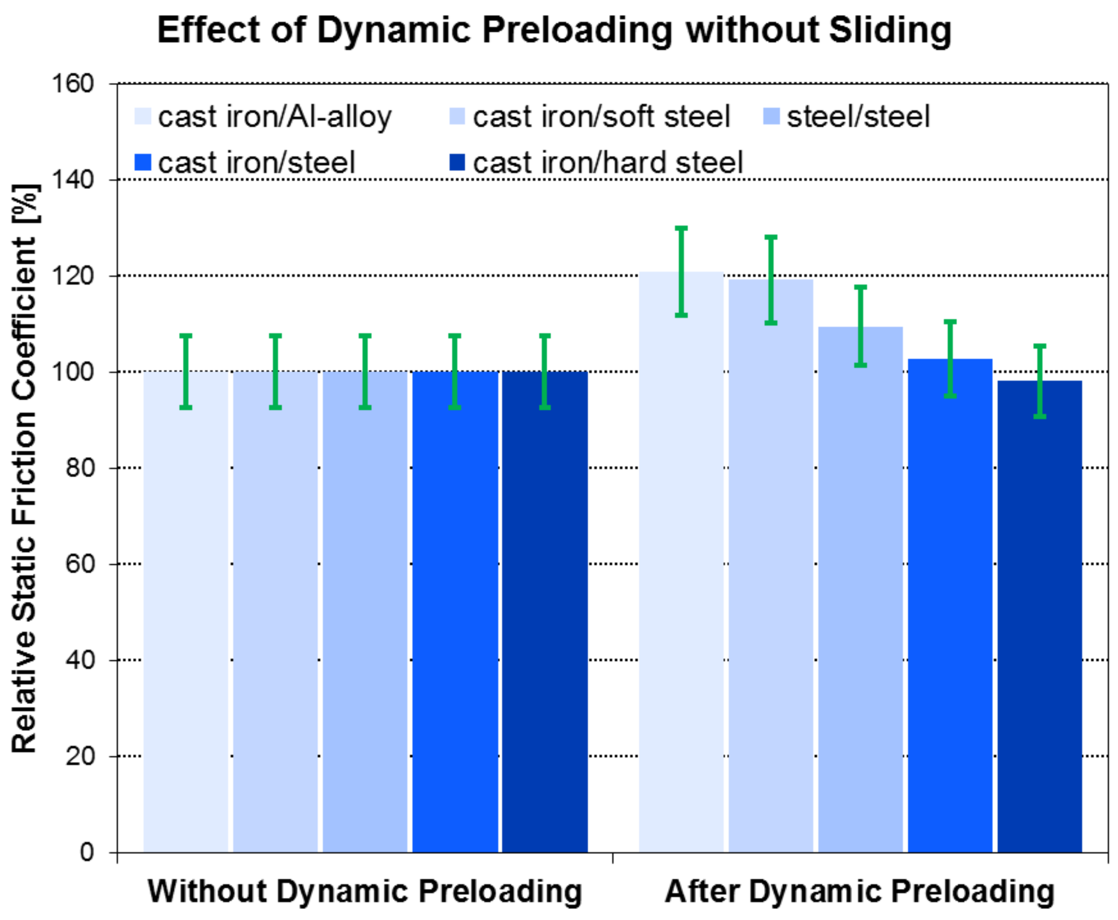
| material combination | | | | | | | | | 3M™ Friction Shims Grade | coefficient of static friction |
|---|---|---|---|---|---|---|---|---|---|---|
| material 1 | Ra [µm] | Rz [µm] | HV 30 | material 2 | Ra [µm] | Rz [µm] | HV 30 | load [MPa] | | |
| S690QL | 0,6 | 4,5 | 280 | GJS-700 | 0,8 | 5,3 | 276 | 115 | without | 0,16 |
| S690QL | 0,6 | 4,5 | 280 | GJS-700 | 0,8 | 5,3 | 276 | 115 | 25 | 0,64 |
| 18CrNiMo7-6 | 1,4 | 6,0 | 213 | GJS-700 | 0,8 | 5,3 | 276 | 115 | 25 | 0,66 |
| GJS-700 | 0,8 | 5,3 | 276 | GJS-700 | 0,8 | 5,3 | 276 | 50 | 25 | 0,73 |
| GJS-700 | 0,8 | 5,3 | 276 | GJS-700 | 0,8 | 5,3 | 276 | 100 | 25 | 0,67 |
| S690QL | 1,6 | 8,0 | 189 | 18CrNiMo7-6 | 1,6 | 8,3 | 290 | 175 | 25 | 0,48 |
| 42CrMo4V | 1,5 | 7,4 | 309 | GJS-700 | 1,9 | 11,2 | 273 | 225 | 25 | 0,48 |
| GJS-400 | 1,4 | 9,5 | 140 | GJS-400 | 1,4 | 9,5 | 140 | 50 | 25 | 0,63 |
| GJS-400 | 1,4 | 9,5 | 140 | GJS-400 | 1,4 | 9,5 | 140 | 100 | 25 | 0,52 |
| 18CrNiMo7-6 | 3,3 | 13,2 | 290 | 42CrMo4V | 3,5 | 13,5 | 312 | 115 | 25 | 0,38 |
| S460 | 1,7 | 7,6 | 183 | 42CrMo4V | 1,5 | 5,3 | 317 | 50 | 25 | 0,75 |
| S460 | 2,6 | 14,9 | 184 | S355 | 2,0 | 11,3 | 162 | 50 | 25 | 0,75 |

S690QL: High tensile fine grained steel
42CrMo4V: Steel for quenching and tempering
S355, S460: Structural steel

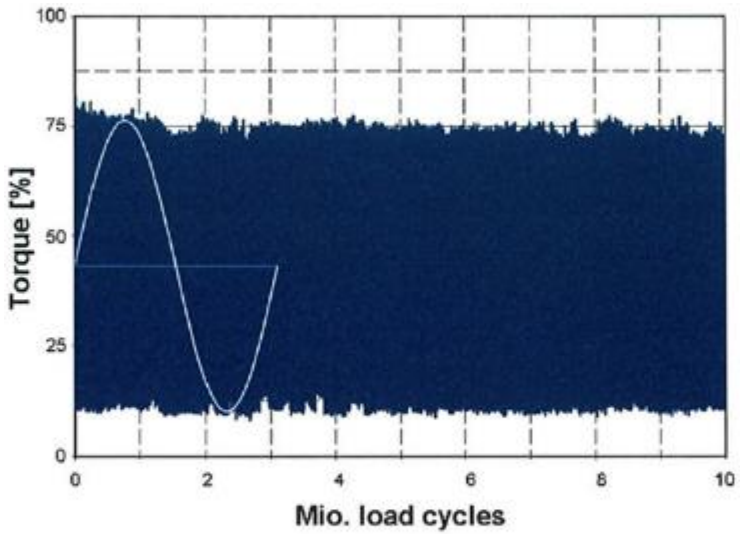
GJS-700 & -400: Spheroidal graphite cast iron
18CrNi Mo7-6: Case hardening steel

**Note:** For application specific data tests need to be carried out with test specimens made out of component representative material and surface machining.

# Proven long term durability for several material combinations




The effect of a dynamic preloading ($10^7$ load cycles with up to 80 % of maximum torque) is very limited and depends on contact materials. In some cases, in particular when softer materials are the counterparts, a slight increase in static friction coefficient has been found.



# 3M™ Friction Shims: Typical specification

## *3M™ Friction Shim Grade 25*

**Rohscheibe / BASE PART**

| | |
|---|---|
| Stahl C75 S 1.1248 nach DIN EN 10132-4<br>STEEL ACC. TO EN 10132-4 (C75S) 1.1248 | Vergütet<br>QUENCHED AND TEMPERED |
| Dicke vor der Beschichtung **<br>THICKNESS BEFORE COATING** | |

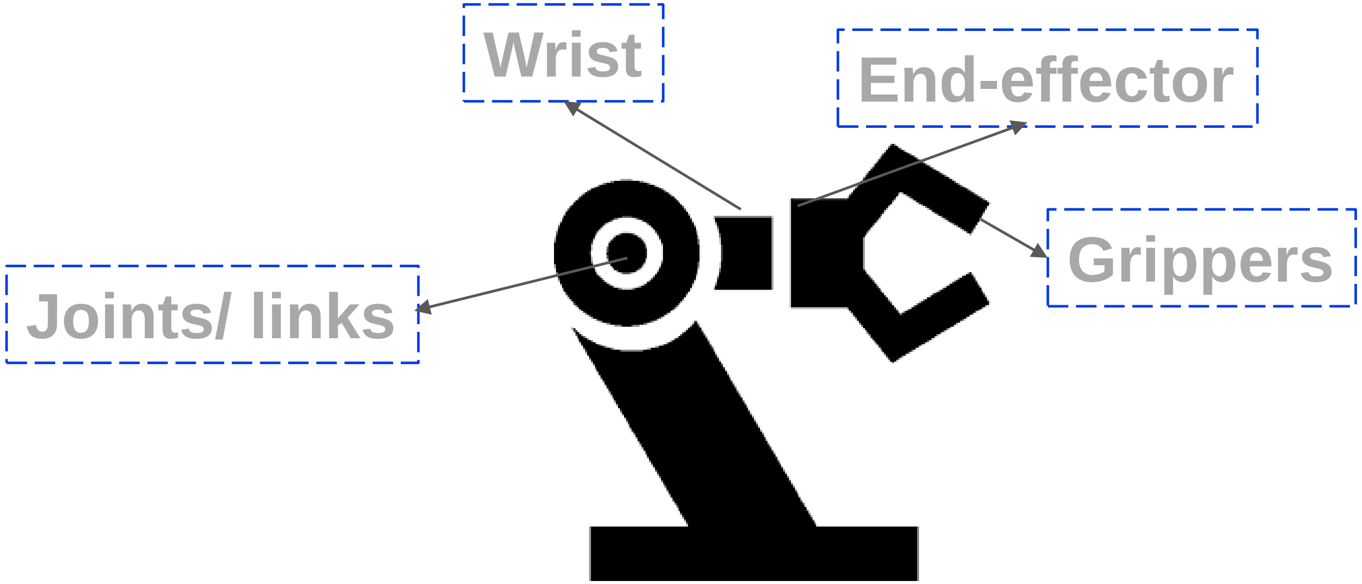
**Beschichtung / COATING**

| | |
|---|---|
| Komplett 3M™ Friction Shim Grade 25 beschichtet<br>COMPLETELY COATED WITH 3M™ Friction Shim Grade 25 | Ni-P - Diamant-Dispersionsschicht<br>EN - DIAMOND COMPOSITE LAYER |
| Matrixmaterial<br>MATRIX MATERIAL | Chemisch Nickel-Phosphor<br>ELECTROLESS NICKEL-PHOSPHORUS |
| Matrixschichtdicke*<br>THICKNESS OF MATRIX-LAYER * | 0,013 - 0,017 mm |
| Mittlere Diamantkorngröße D50 % *<br>DIAMOND MEAN PARTICLE SIZE * | 25,0 µm $^{+/-\ 2,0}$ |
| Mittlere Diamantflächenbelegung*<br>AVERAGE DIAMOND COVERAGE ON SURFACE* | 8,0 - 25,0 % |
| Wärmebehandlung<br>HEAT TREATMENT | 150°C, 2 hours |
| Gesamtdicke**<br>TOTAL THICKNESS** | 0,230 - 0,290 mm |

** 3M Specific measurement*

*** Micrometer*

# Parts within a Robotic System with Potential Requirement of Friction Enhancement



# Application in Robotics / End Applications

## Systems in which 3M™ Friction Shims can be used

### End-Application Areas

#### Small-spaced surroundings in work area of robot

- For small-spaced environments small robots (payload capacity between 0.5 kg and 3 kg)
- The wrist area needs more compact design as compared to the robot-base. The wrist has to be small in size to get good access to the application area.
- Friction shims enable smaller design size contact area and therefore smaller part dimensions.

#### High vibrations

- Higher vibrations cause the need for more friction.
- Friction shims offer a high safety buffer.

#### Fast movements/ accelerations

- For fast movement of robotic arms in various directions, low masses and low inertia are desired.
- Friction shims enable smaller design size contact area and therefore smaller part dimensions.

# THANK YOU!

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