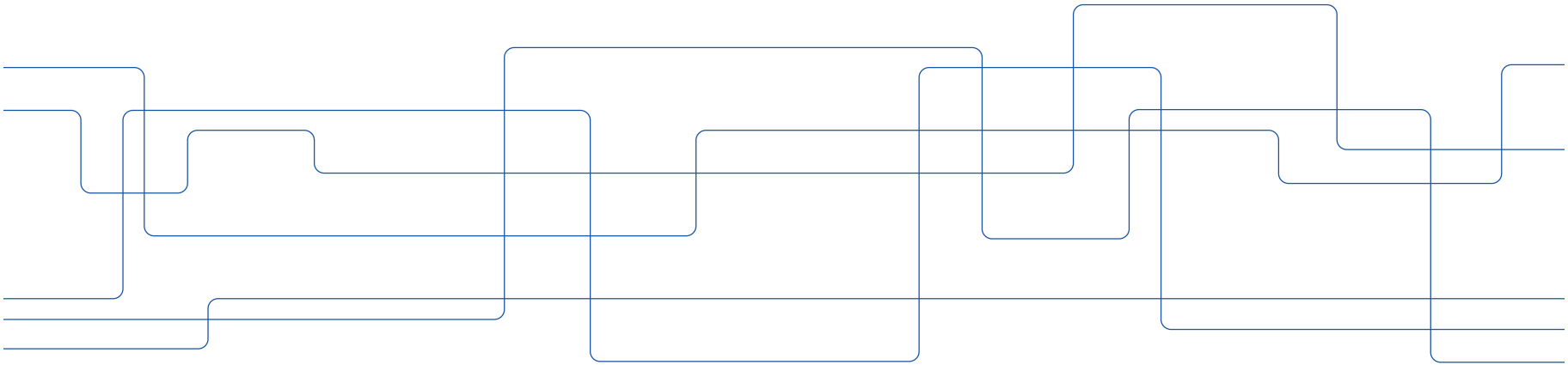
KTH ROYAL INSTITUTE OF TECHNOLOGY

Doctoral Thesis in Machine Design, 2022

Friction in threaded fasteners influence of materials and tooling

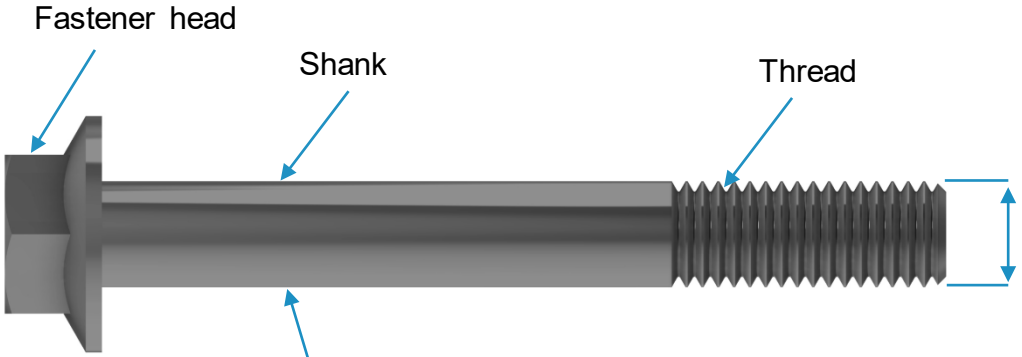
MAYANK KUMAR

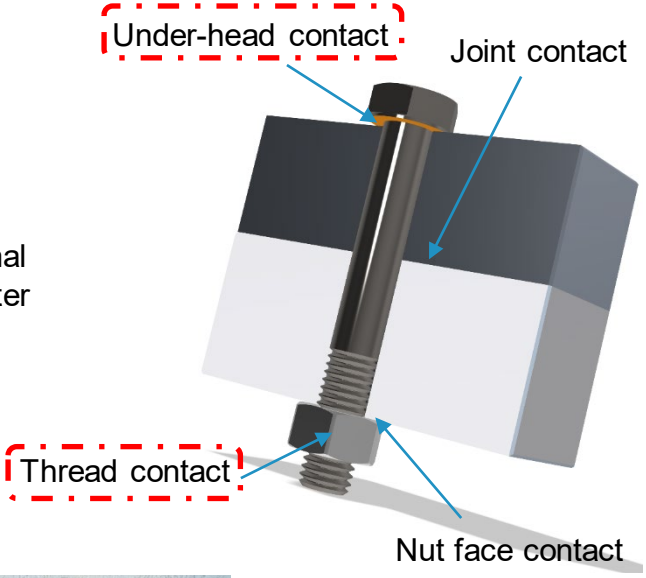
Supervisors: *Prof. Sergei Glavatskih; Dr. Erik Persson, Dr. Ellen Bergseth, Prof. Ian Sherrington*



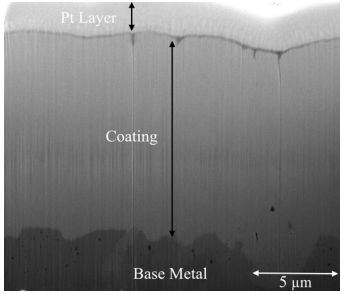
11/23/2022 ISBN: 978-91-8040-351-1 TRITA-ITM-AVL 2022:28

What is a threaded fastener joint?





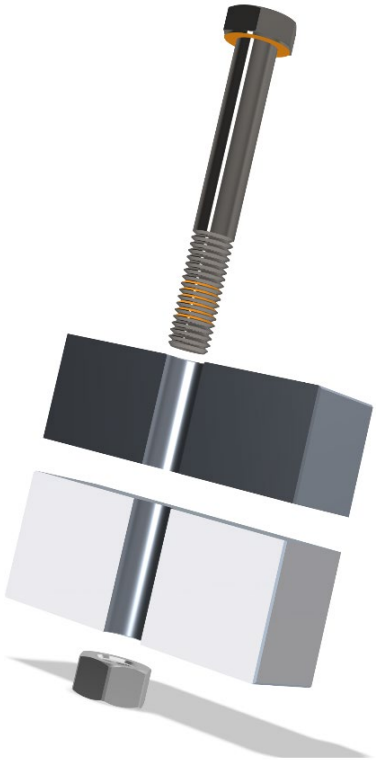
Zn-based coating [free from Cr(VI)]



End-of-Life Vehicles directive[1]

1. End-of-LifeVehicles, url = "https://ec.europa.eu/environment/topics/waste-and-recycling/end-life-vehicles_en", month = september, year = 2000.

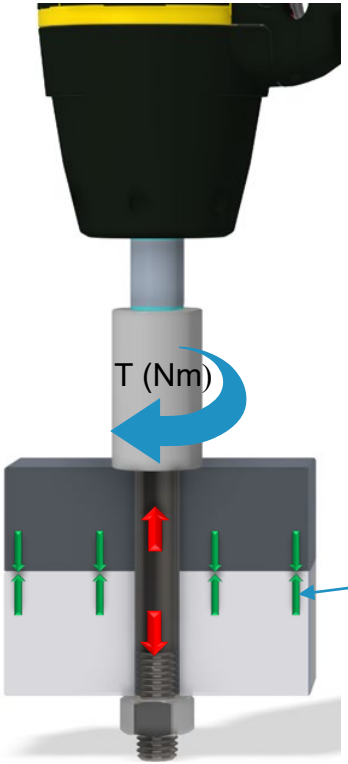
Why do we need threaded fastener joints?

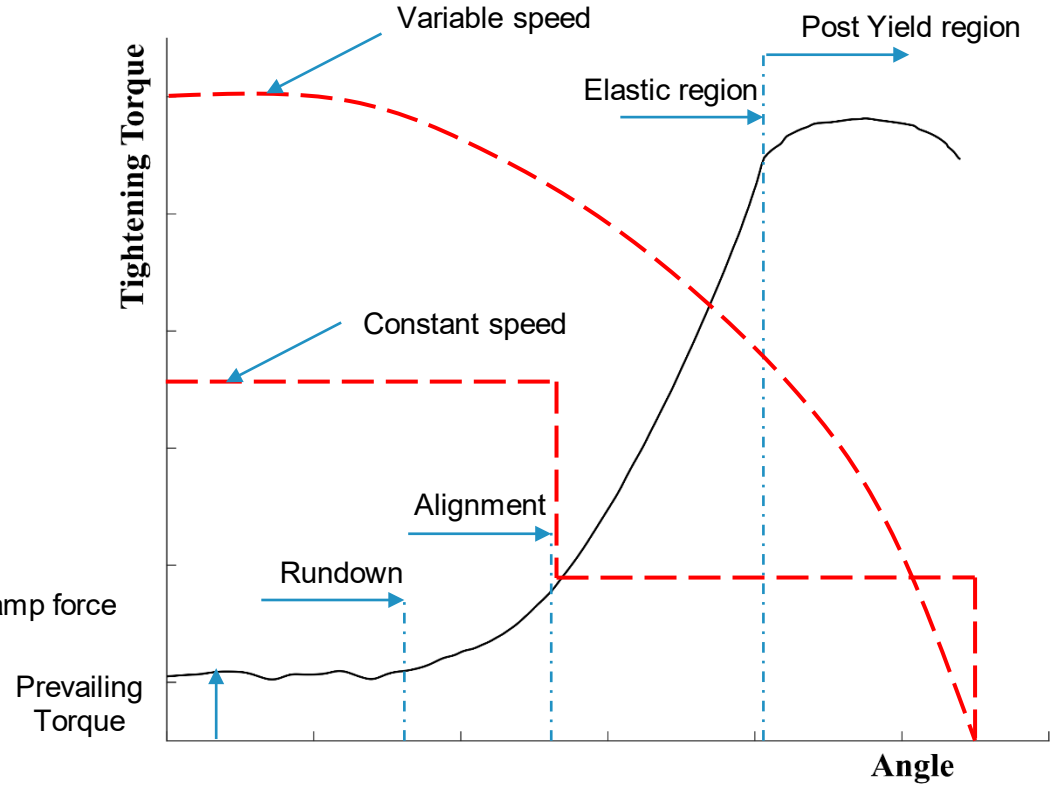


Design for disassembly[2]

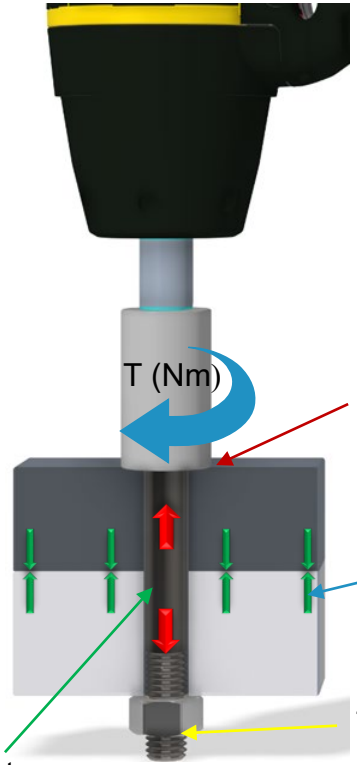
2. Talens Peiró, L., Ardente, F. and Mathieux, F. (2017), Design for Disassembly Criteria in EU Product Policies for a More Circular Economy: A Method for Analyzing Battery Packs in PC-Tablets and Subnotebooks. Journal of Industrial Ecology, 21: 731-741.

What is tightening?

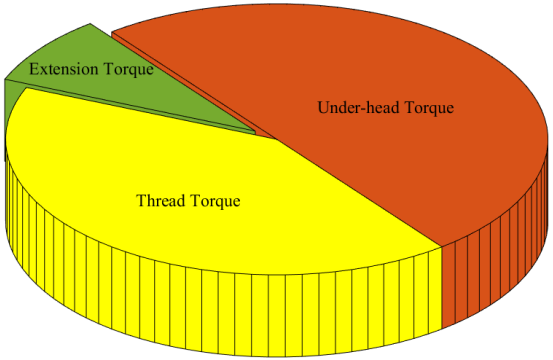




Where does the tightening torque go?

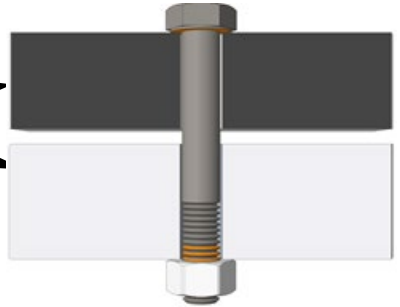


Distribution of the tightening torque



Clamp force is the key.

Joint separation

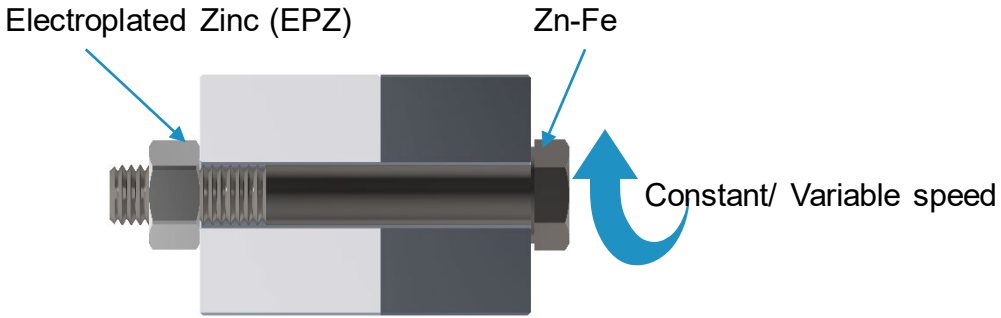


Fastener breakage

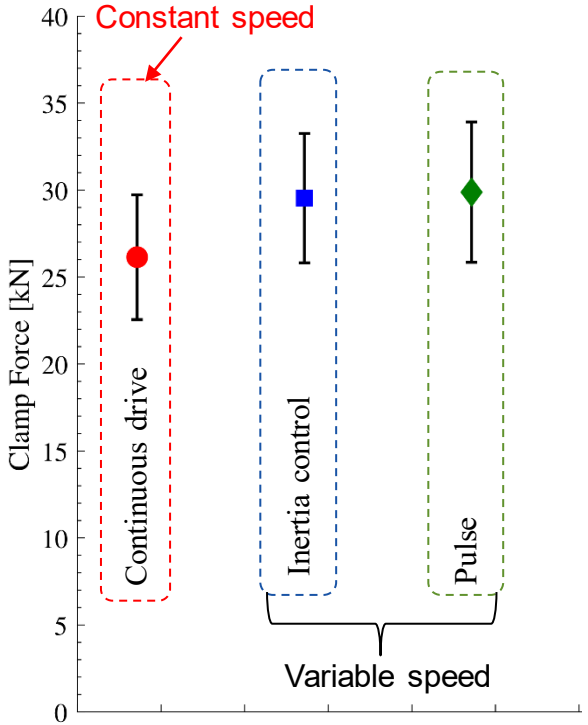
Research questions

- What are the **impacts of different toolings** on the threaded fastener friction response?
- What is the **nature of friction** variation during variable speed tightening?
- How do **surface hardness and topography** influence friction during torque control tightening?
- How does **joint surface cleaning** influence friction response of threaded fasteners with Zn-based coatings?
- How do **storage conditions** of Zn-flake coated fasteners influence their friction response?
- Do we need to machine **AM components** to achieve low friction?

What are the impacts of different toolings on the threaded fastener friction response?

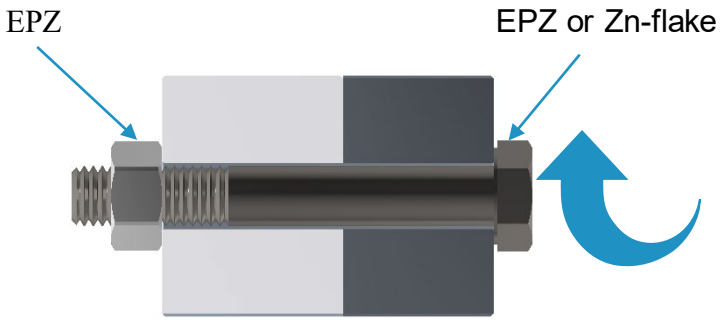


Tightening speed may impact.

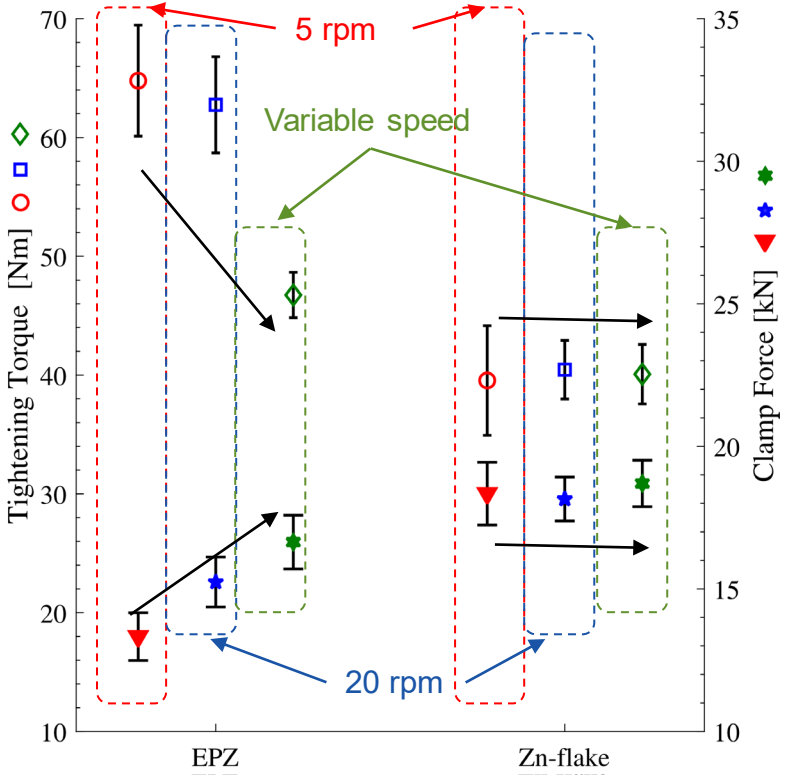


What is the nature of friction variation during variable speed tightening?

Torque plus Angle control
[Constant/ Variable speed]



Tightening speed has an impact on friction depending on coating type.

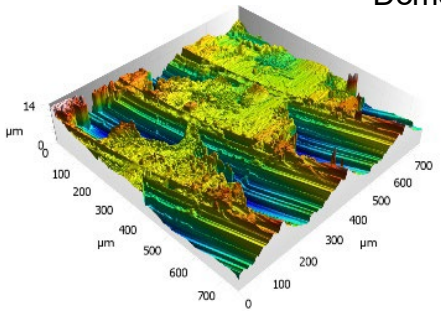


What is the nature of friction variation during variable speed tightening?

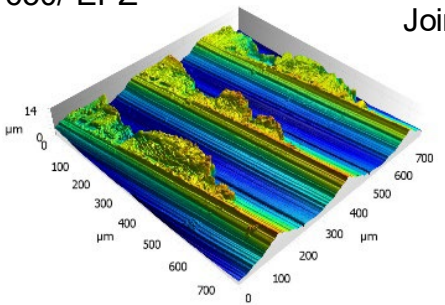
Domex 650/ EPZ

Joint surface

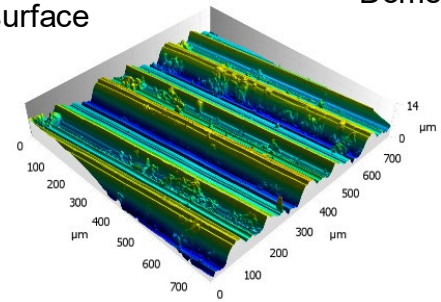
Domex 650/ Zn-flake



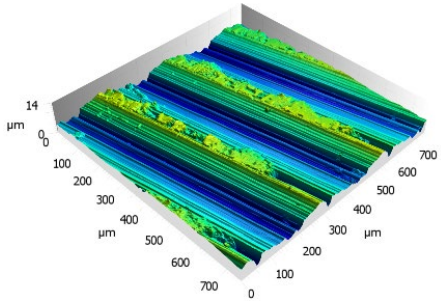
5 rpm



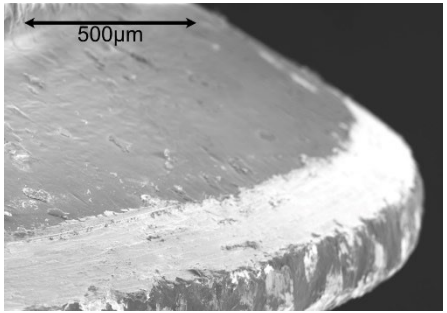
Variable speed

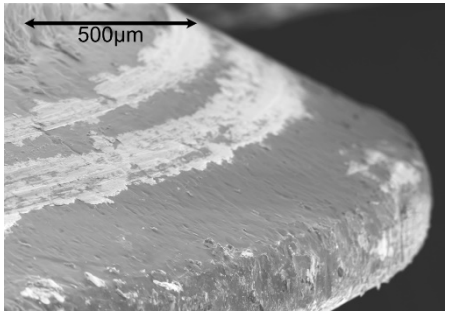


5 rpm

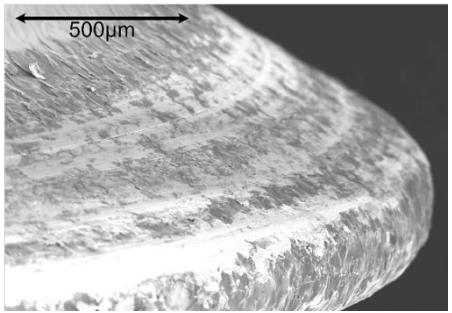


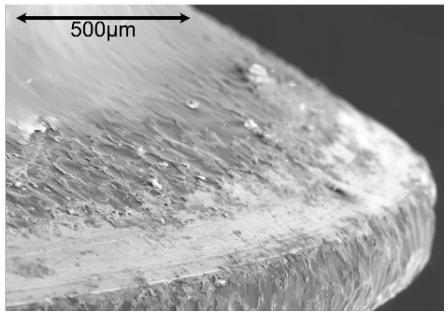
Variable speed





EPZ/ EPZ

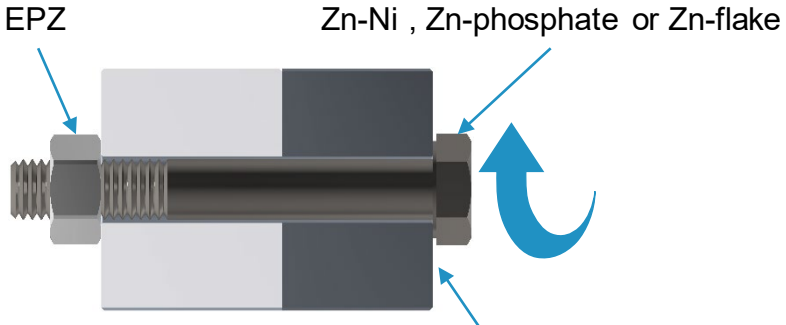




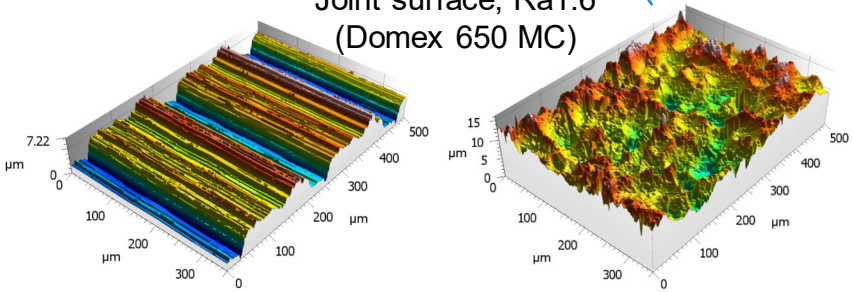
Zn-flake/ EPZ

Tightening to a load
Constant speed

How do surface hardness and topography influence friction during torque control tightening?

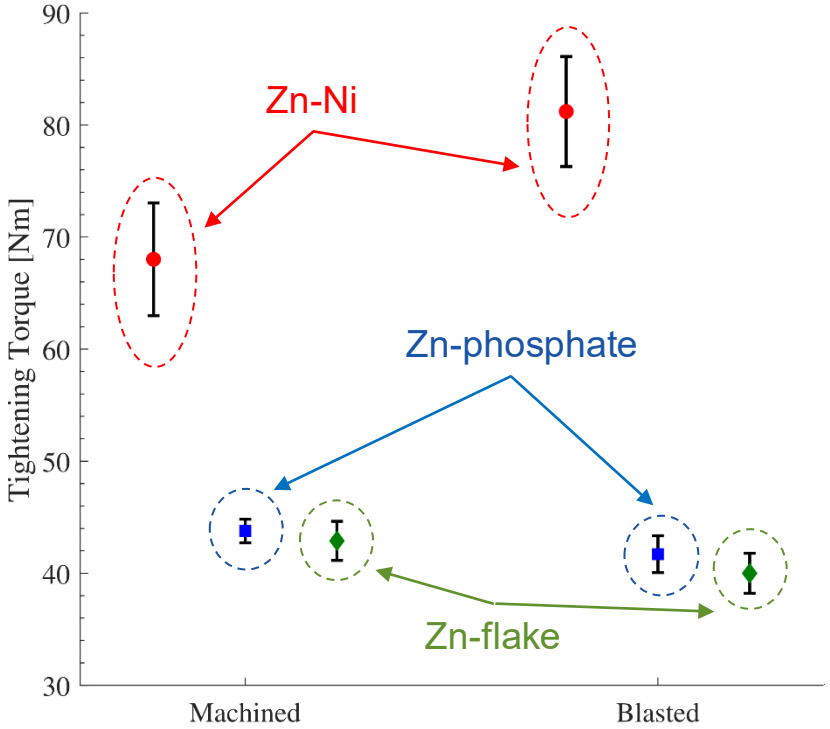


Joint surface, Ra1.6
(Domex 650 MC)

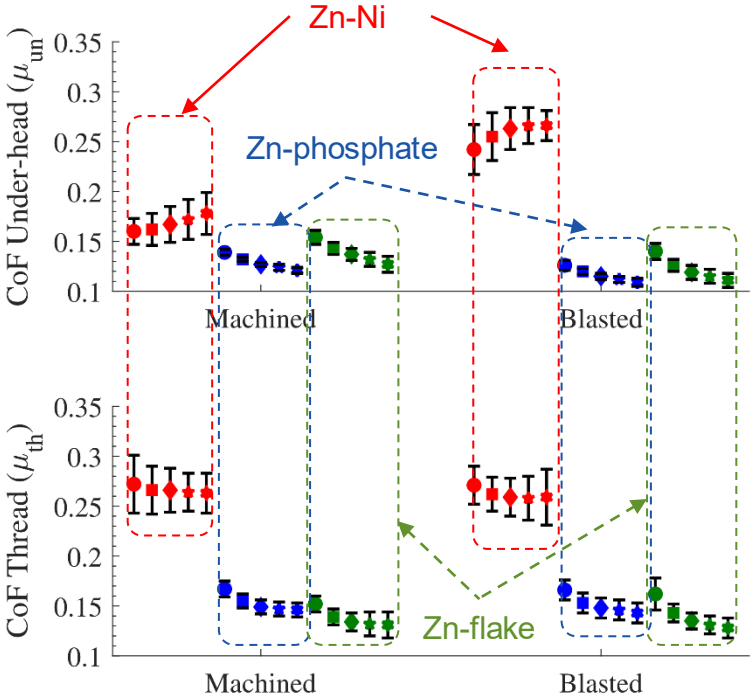


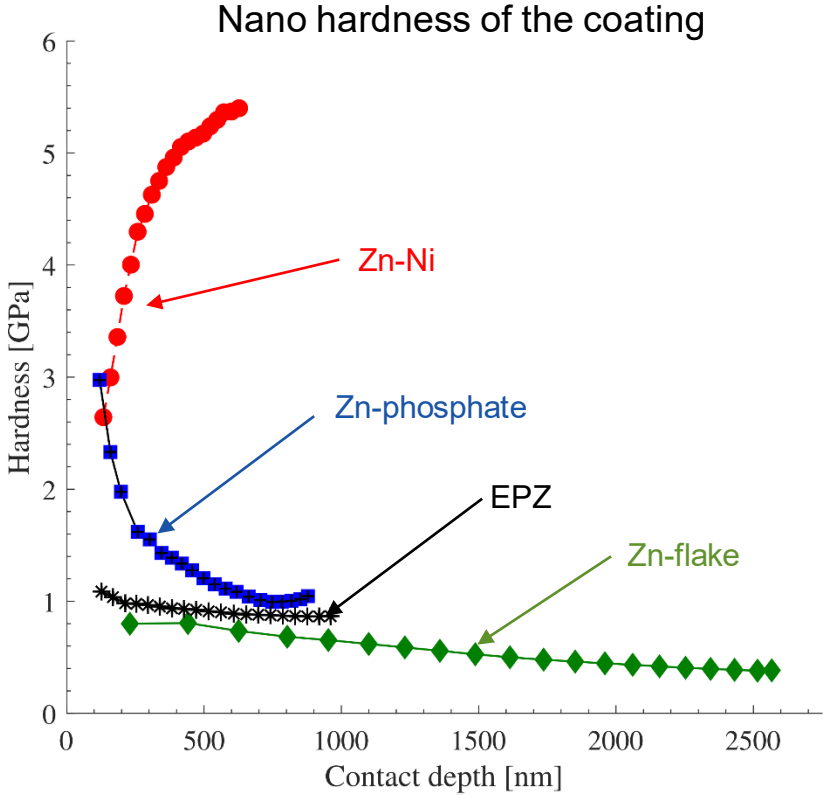
Machined

Blasted



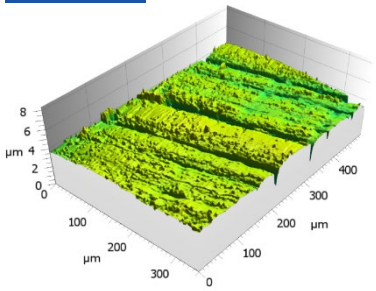
How do surface hardness and topography influence friction during torque control tightening?



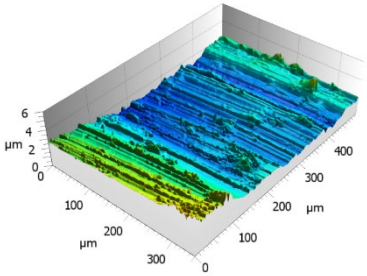


How do surface hardness and topography influence friction during torque control tightening?

Machined

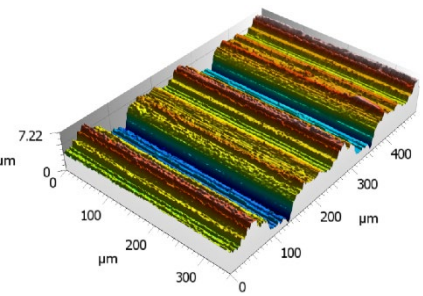


Blasted

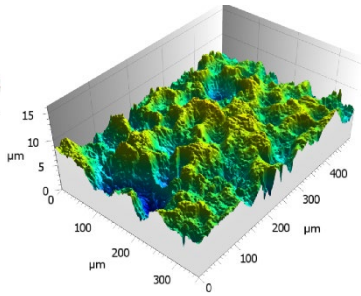


Joint surface
(Domex 650MC)

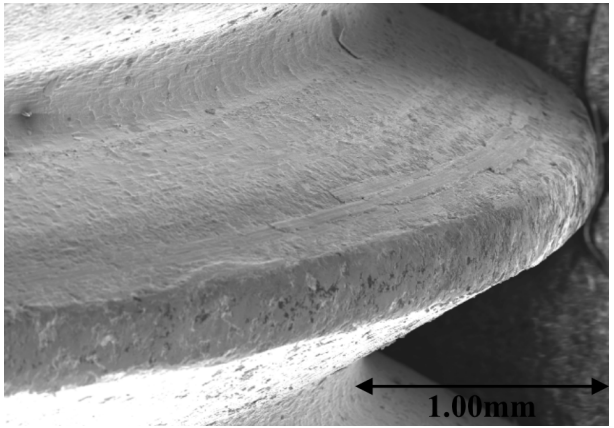
Machined



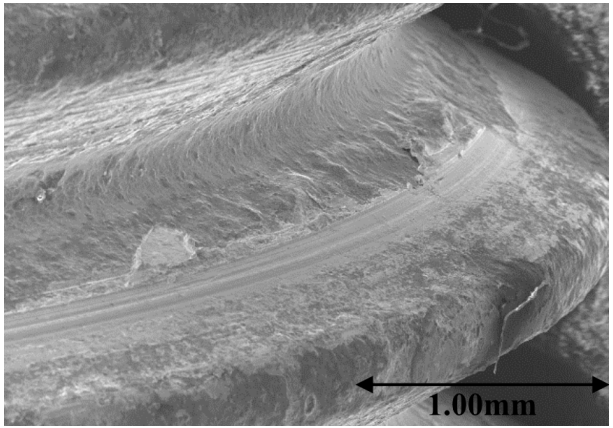
Blasted



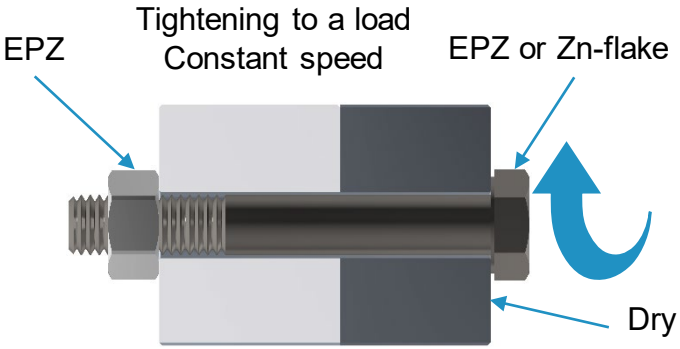
Zn-Ni (Harder than EPZ)

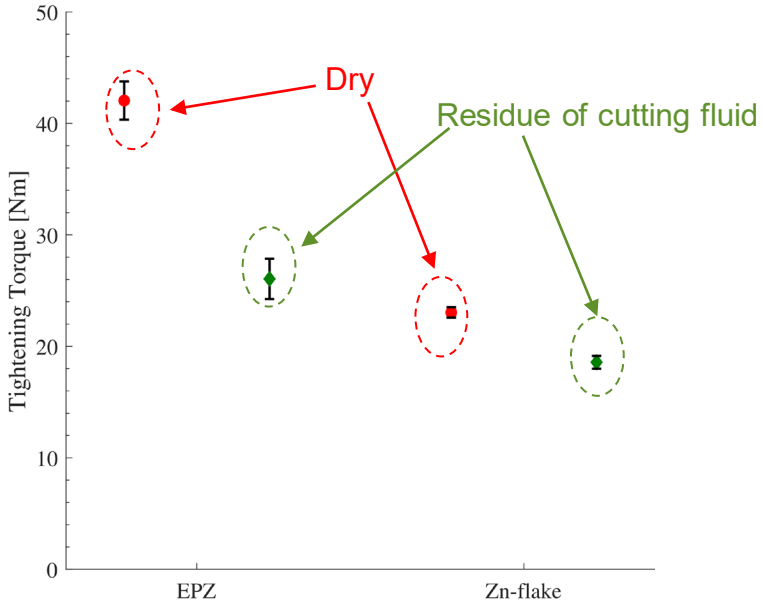


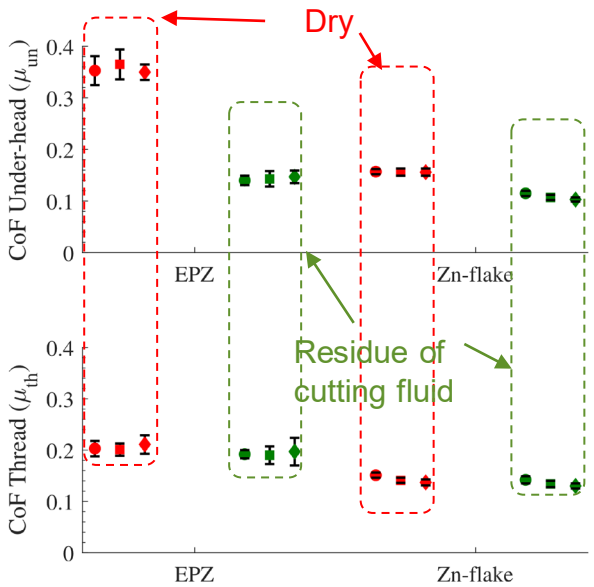
Zn-flake (Softer than EPZ)



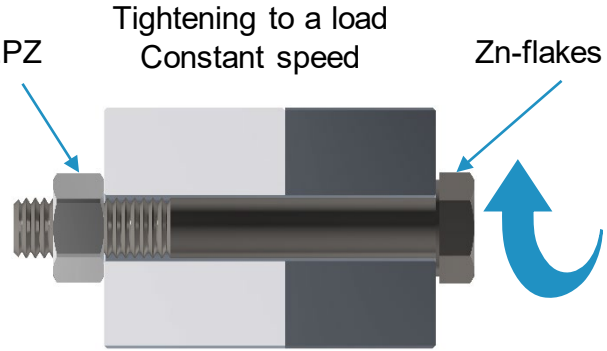
How does joint surface cleaning influence friction response of threaded fasteners with Zn-based coatings?

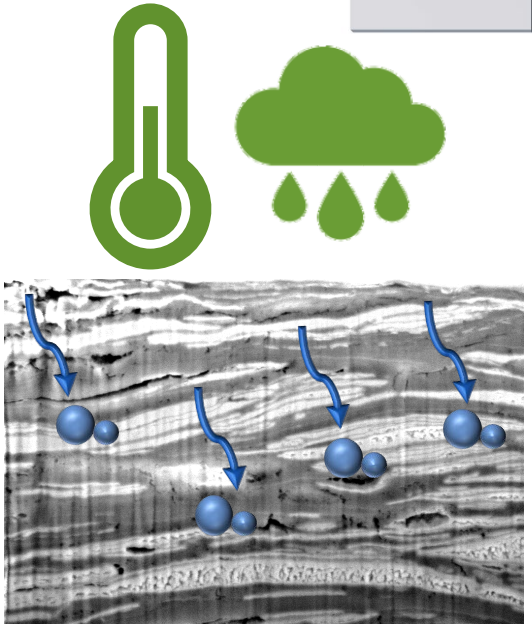




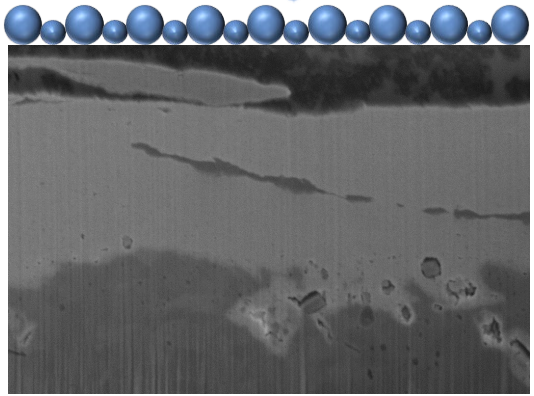


How do storage conditions of Zn-flake coated fasteners influence their friction response?

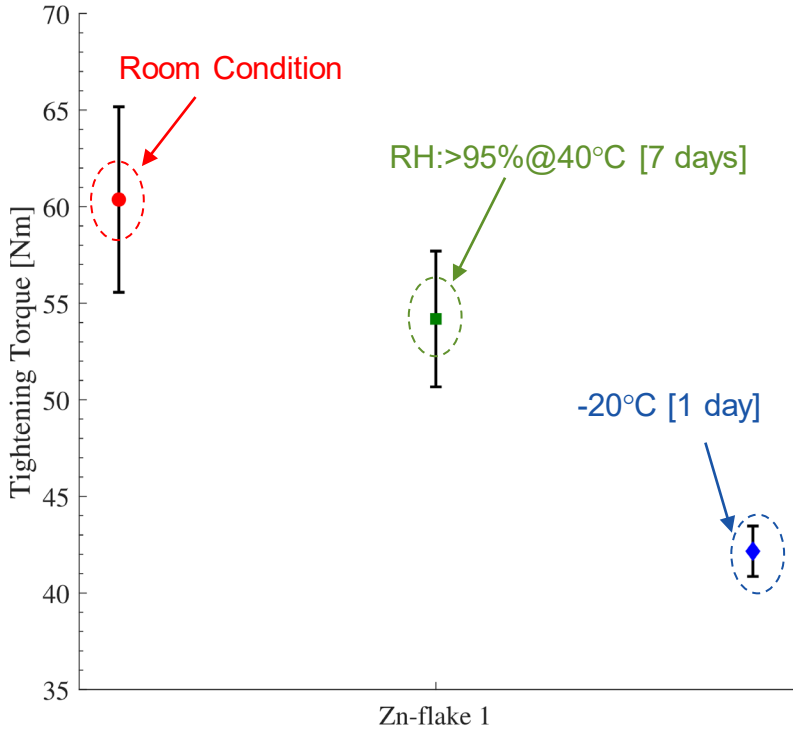




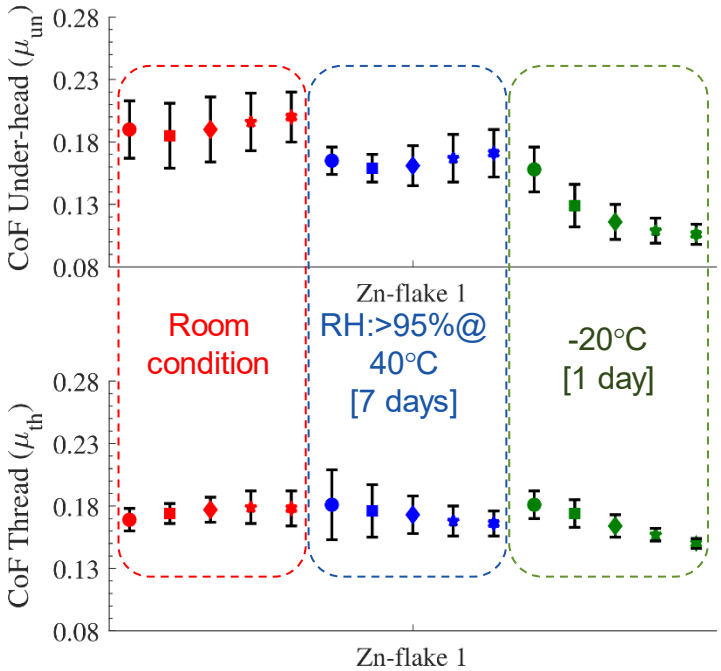
Absorption



Adsorption



How do storage conditions of Zn-flake coated fasteners influence their friction response?



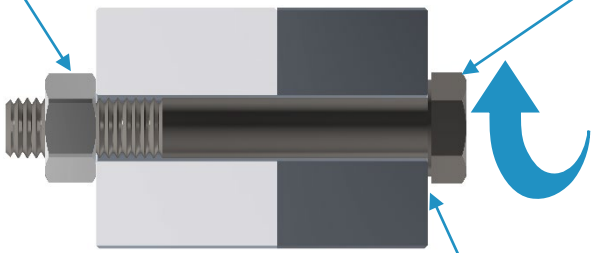
CoF in under-head contact is more influenced by the change in storage condition than thread contact.

Do we need to machine AM components to achieve low friction?

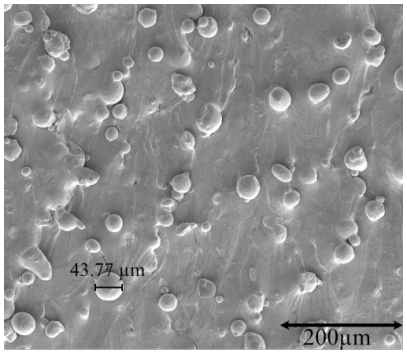
Tightening to a load
Constant speed

EPZ

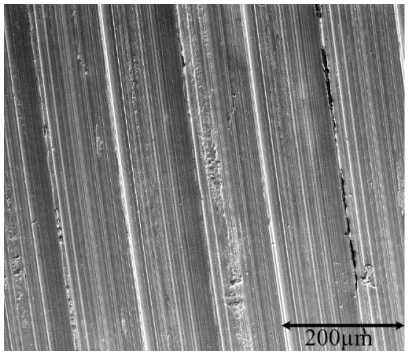
Plain or Zn-Fe



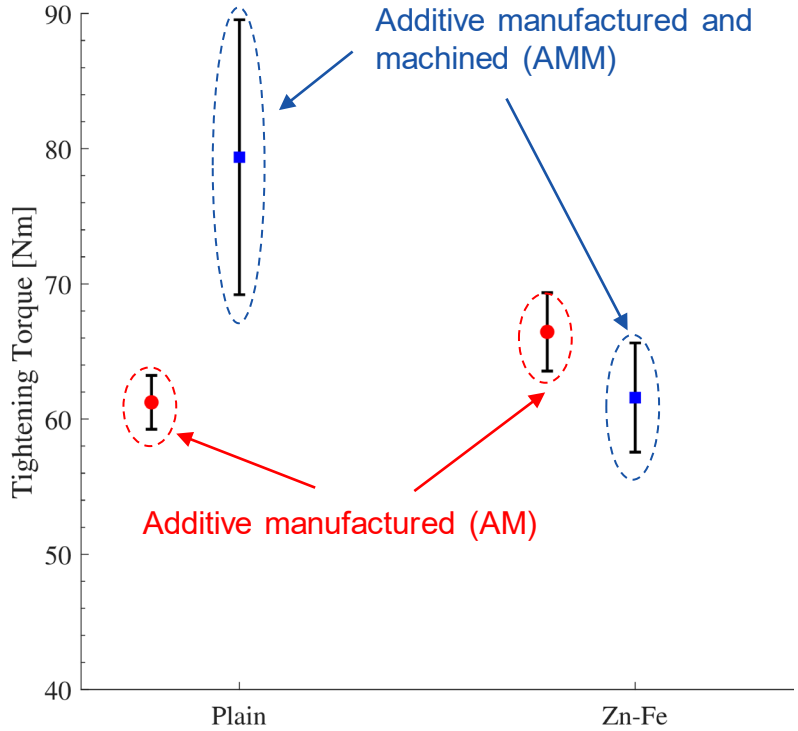
Joint surface



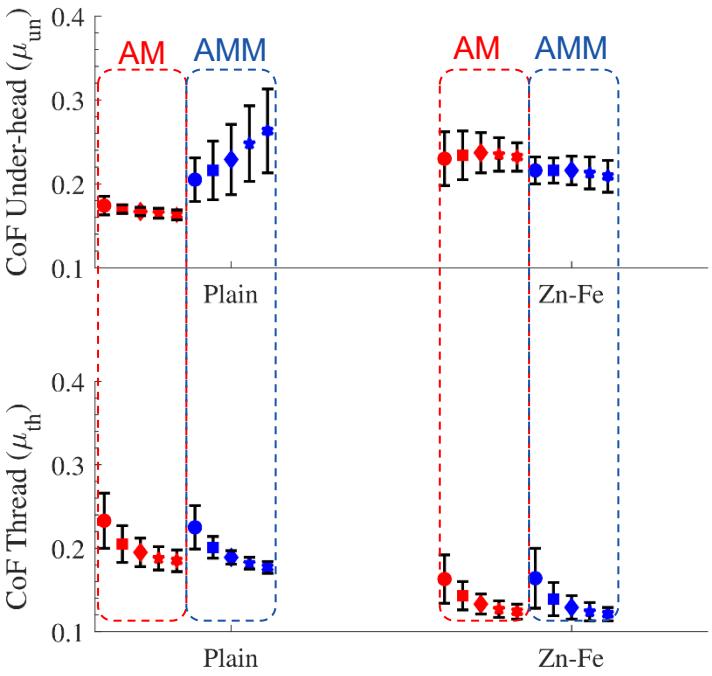
Additive manufactured (AM)



Additive manufactured and machined (AMM)

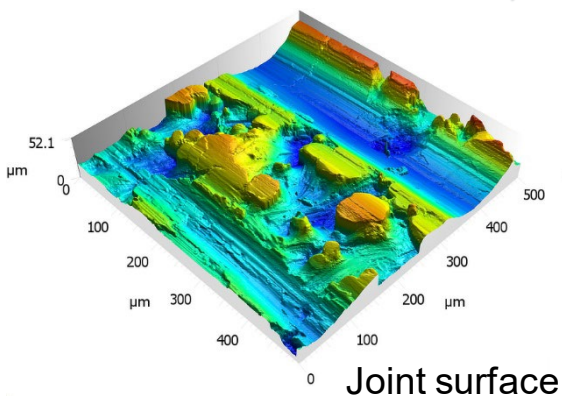


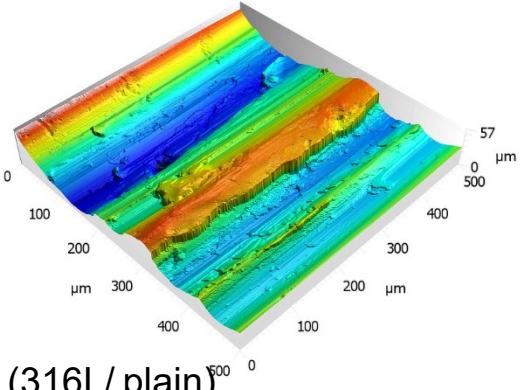
Do we need to machine AM components to achieve low friction?



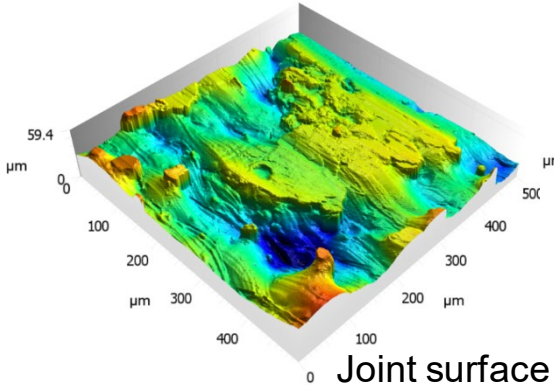
Additive manufactured (AM)

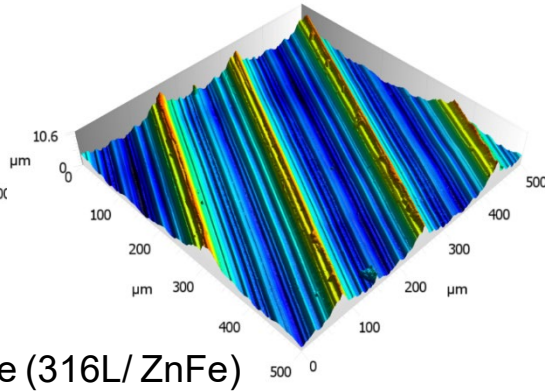
AM and machined (AMM)





Joint surface (316L/ plain)





Joint surface (316L/ ZnFe)

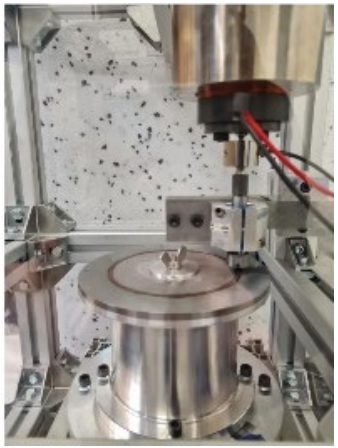
Key takeaways

- The scatter in clamp force is mainly affected by the scatter in the CoF rather than the scatter in the assembly tool torque.
- Impact of tightening speed on friction is dependent on coating types.
- The residue of cutting fluid on the surface will reduce the CoF compared clean surface.
- Condensation on the surface of coating will reduce CoF.
- For the hot/humid conditions, the reduction in CoF is due to the probable formation of zinc oxide in the zinc-based coating.
- Even a non-finished surface of additive manufactured material and fastener without surface coating can give a low scatter in CoF.

Conclusions

- The influence on the CoF due to changes in the materials and tightening parameters is the lowest when a threaded fastener with a soft coating is used.
- Soft coating tends to be damaged more, leading to an increase in the scatter in CoF when the fastener is retightened and may increase risk of corrosion.
- A hard coating such Zn-Ni destroys the softer surface of the joint, which may lead to discarding the joint altogether but have a low risk of corrosion.
- The coating without a top coat will shows a higher variation in CoF in most cases as when it comes in contact with similar coating.
- An oiled threaded fastener (with and without coating) gives the lowest scatter in CoF during tightening and retightenings but will change with time due to evaporation of the oil from the fastener
- By monitoring the tightening process and joint friction, less rework needs to be carried out in production.

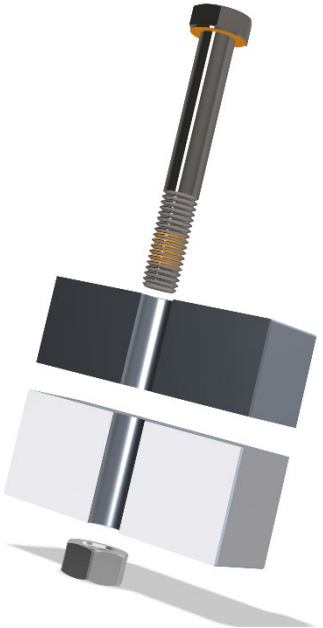
Future work



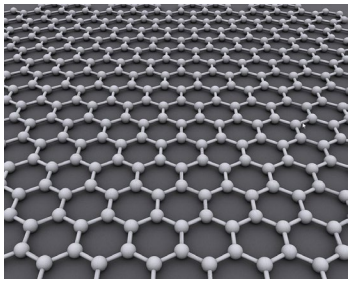
Friction model using pin-on-disc

https://www.hubs.com/guides/metal-3d-printing/

Novel Manufacturing



Disassembly/loosening



AlexanderAUS, CC BY-SA 3.0 <https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons

Novel coating: Graphene based

Service/aftermarket

https://www.nipponpaint-holdings.com/en/rd/technology/20201111/

Electrodeposited paint

Paper A	Erik Persson, **Mayank Kumar**, Christian Friberg, Nils Dressler ”Clamp Force Accuracy in Threaded Fastener Joints Using Different Torque Control Tightening Strategies”. SAE Technical Paper 2021-01-5073. 2021
Paper B	**Mayank Kumar**, Erik Persson, Ellen Bergseth, Ian Sherrington, Sergei Glavatskih ”Assembly of joints using threaded fasteners: Influence of fastener coating and joint surface topography”. To be submitted.
Paper C	**Mayank Kumar,** Erik Persson, Sergei Glavatskih ”Influence of cutting fluid on reliability of threaded fastener joints”. SAE Technical Paper 2019-01-2300. 2019
Paper D	**Mayank Kumar,** Erik Persson, Ian Sherrington, Sergei Glavatskih ”Changes in friction of zinc flake coated threaded fasteners due to humidity, temperature and storage duration”. Tribology International. 2022
Paper E	**Mayank Kumar,** Erik Persson, Ian Sherrington, Sergei Glavatskih ”Variable speed tightening of threaded fastener joints: Improving productivity and operator comfort”. To be submitted.
Paper F	**Mayank Kumar,** Erik Persson, Ian Sherrington, Sergei Glavatskih ”Friction of threaded fasteners when clamping additive manufactured components”. To be submitted.

Link to the thesis