Modeling a Bolted Joint for Dynamic Tightening Simulation and Control

Friction Modeling and Clamp Force Estimation

Nils Dressler (Industrial Ph.D.) Atlas Copco Industrial Technique

Summary

A model for threaded fastener tightening was developed to create an environment to study dynamic tightenings. That model includes components representing friction torques and non-linear displacement-stress relationships.
The behavior for the friction torque model is presented in detail.

A user interface to handle the complexity of finding model parameters for standard fasteners and simple joint geometries was developed.
A testbed for model verification and prototyping of control algorithms has been developed.

Model for Friction in Threaded Fastener Joints

A model that can be used for the friction components (Under Head Friction and Thread Friction) has been developed to model the friction losses with varying normal force (clamp force in the case of a bolted joint) and angular velocity dependent friction coefficients.

$$J\dot{\omega} = \tau_{in}(t) - \tau_{out} - \tau_{frict}(\omega, t)$$

$$\mu(\dot{\omega}) = \tanh(c_0\omega)\left(c_1 + c_2|(\omega)| + c_3 e^{(-c_4|\omega|)}\right)$$

$$\tau_{frict} = C_F(t)\mu(\omega)r$$

Inputs : ω, τ_{in}, C_F Outputs : τ_{out} Losses : τ_{frict}

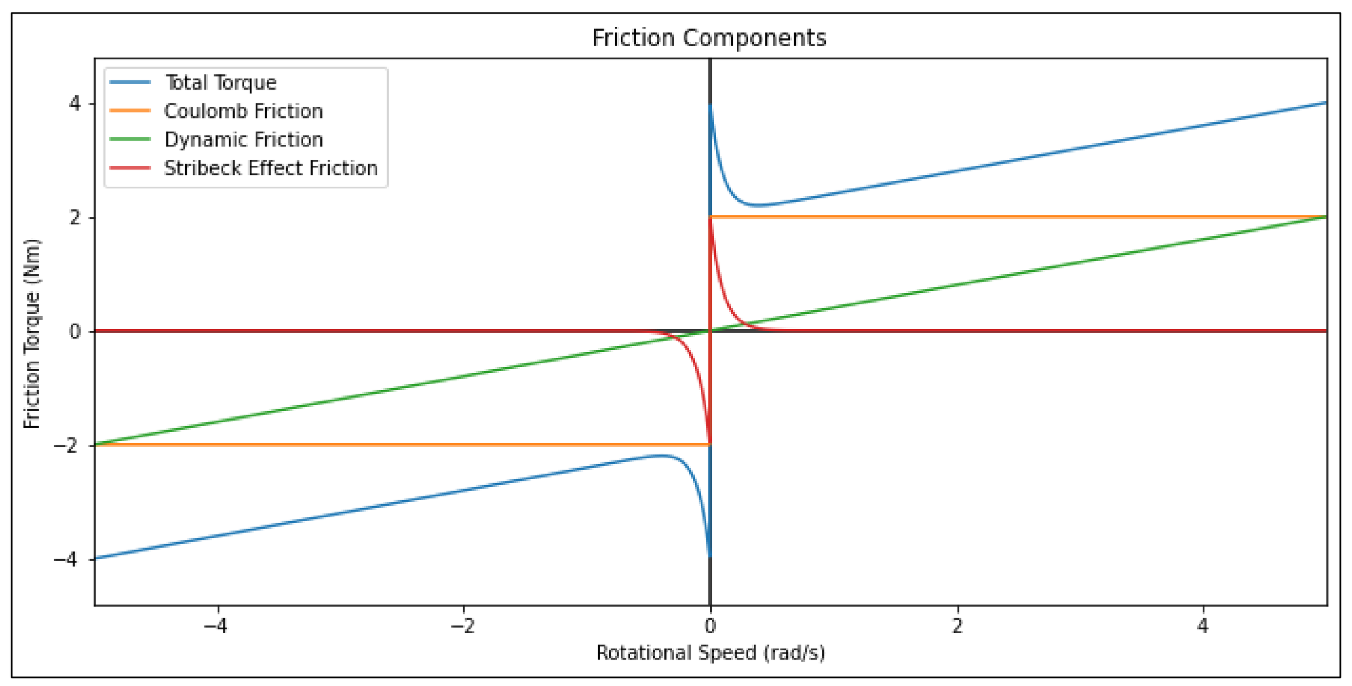

Figure 1. Friction torque according to the friction model. Torque components divided in the share of coulomb friction, dynamic friction and Stribeck friction.

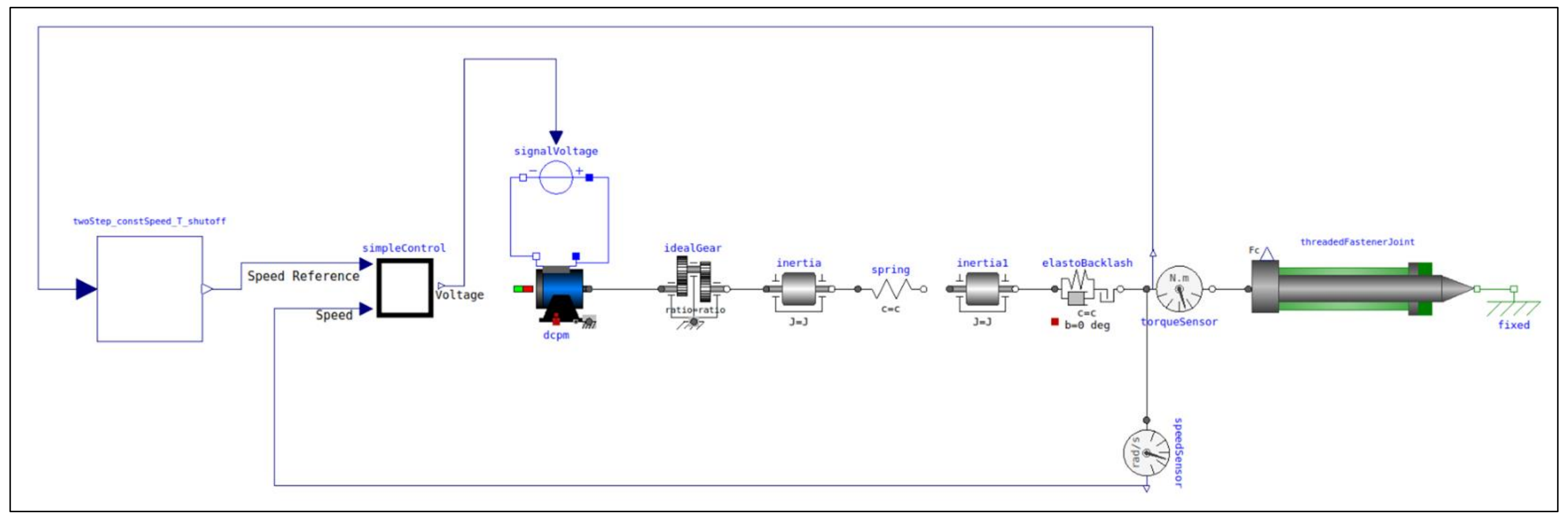

Figure 2. Modelica Implementation of a driveline and threaded fastener model used for evaluation of control strategies

TightSim: User interface for Tightening Simulations

In tightenings, the variety of applications is quite large, where every joint and fastener combination needs a different set of parameters. This is a major challenge since the complexity of gathering the needed parameters is high.
In order to support a simulation user with the collection and calculation of the needed parameters, a graphical user interface for the Modelica simulation has been developed.

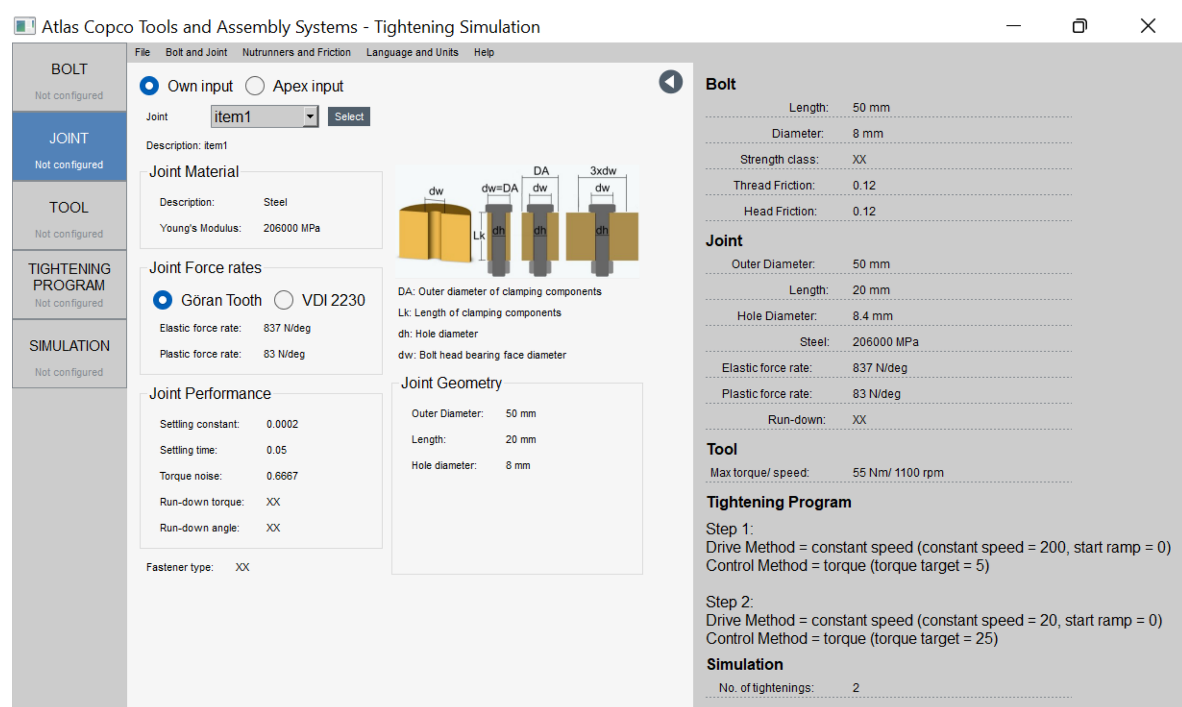

Figure 3. Graphical User Interface for calculation and collection of parameters for tightening simulations - TightSIM

With the user interface, the simulation is provided with predefined tool parameters as well as derived and calculated joint and driveline parameters. This simplifies the usage of the model a lot and enables a wider range of engineers to use the model to gain further insight in the behavior of threaded fastener joints during tightening.

Figure 4. Typical tightening tool from Atlas Copco, for which more advanced tightening control strategies are desirable. Here a n EVT Tensor SB Tool.

Development of a Tightening Control Testbed

In a Master Thesis a testbed for implementation of different tightening control algorithms has been designedd and commissioned.

The testbed offers a great opportunity to quickly verify control algorithms on real hardware. The code generation is done through the MATLAB Coder and Simulink.

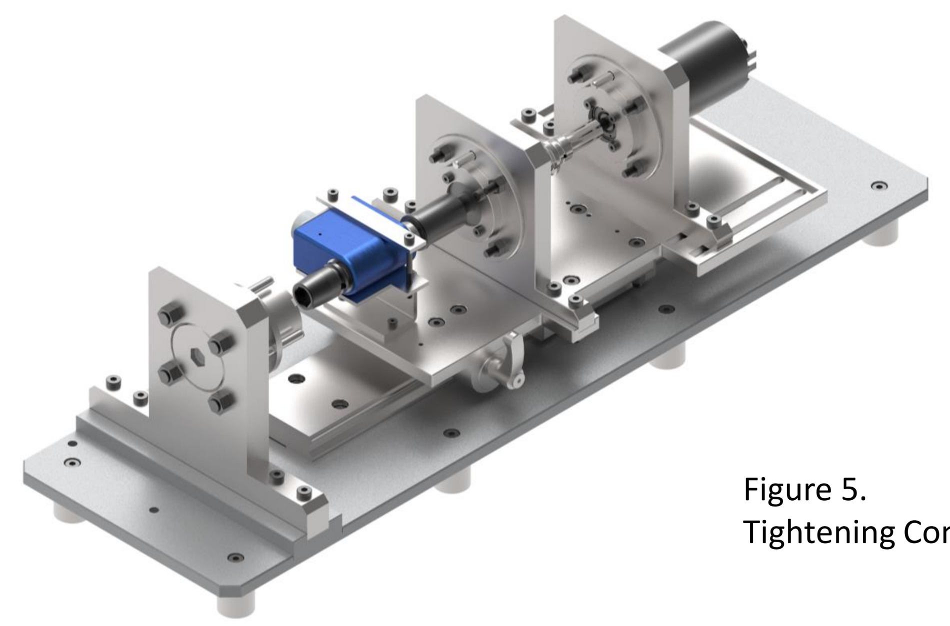

Figure 5.
Tightening Control Testbed

Key Components
- Brushed DC Permanent Magnet Motor
- Planetary Gearbox
- Inline Torque Transducer (IRTT)
- Controller : C2000 Delfino LAUNCHXLF28379D

Related Publications

[1] Persson, E.V., Kumar, M., Friberg, C., and Dressler, N., “Clamp Force Accuracy in Threaded Fastener Joints Using Different Torque Control Tightening Strategies,” SAE Technical Paper 2021-01-5073, 2021, doi:10.4271/2021-01-5073.

LINKÖPING UNIVERSITY
DEPT. OF ELECTRICAL ENGINEERING