Implementation of a Bolted Joint Model in Modelica and MATLAB

Nils Dressler
nils.dressler@atlascopco.com
Atlas Copco Industrial Technique, Linköping University

Lars Eriksson
Vehicular Systems, ISY, Linköping University

Introduction

Threaded fasteners are essential machine elements, but the dynamics of tightening—especially friction and embedment effects—are complex.
This research implements and compares bolted joint models in Modelica and MATLAB, focusing on simulation, parameter sensitivity, and validation with experimental data.

System Overview

The bolted joint system is modeled with rotational and translational domains interacting through friction and clamp force. Key phases include:

- **Run-down**: Nut approaches clamped parts.
- **Alignment**: Contact between components.
- **Elastic clamping**: Torque and force increase linearly.

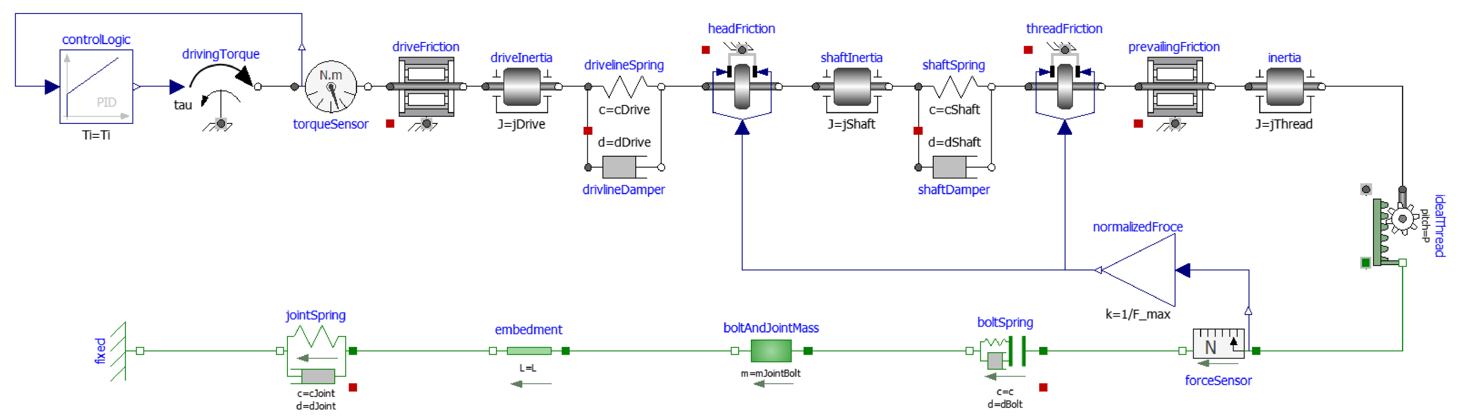

Figure 1: System Model in Modelica.

Model Development

The Modelica and MATLAB implementations include friction, embedment, and tightening phases. MATLAB enables analytical analysis, while Modelica supports modular development.

Figure 2: EVT Tensor SB tool from Atlas Copco.

$$\dot{x} = Ax + Bu + f(x, \theta), \quad \text{where } x \in \mathbb{R}^5$$

In the given model form, A is the system matrix, B is the input matrix, and $f(x, \theta)$ captures the nonlinear terms.
The MATLAB model consists of five state equations. Four of these are second-order differential equations governing the dynamics of translational and rotational motion, based on the principles of Newtonian mechanics. The fifth equation describes the behavior of the embedment, capturing its influence on the system.

Results and Discussion

Simulations were validated against experimental data. MATLAB provided faster simulations and a model structure that can be extracted, while both implementations effectively captured tightening dynamics.

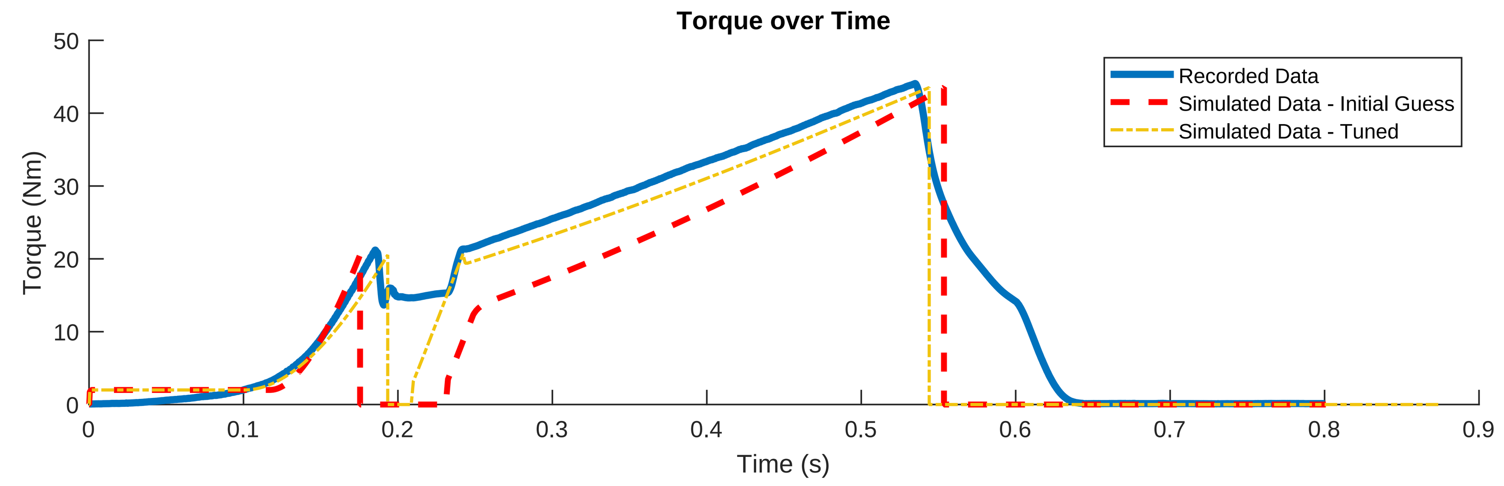

Figure 3: Torque evolution during tightening phases.

Conclusions

The developed models effectively simulate bolted joint tightening dynamics, providing valuable insights into the tightening process and enabling analytical evaluation of model properties.
An important observation is that Modelica facilitates faster modeling and easier implementation of changes, while MATLAB excels in debugging and offers greater flexibility for applying modeling techniques and customizations.
Future work will focus on observability analysis and utilizing the models for advanced control strategies.

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